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ANALYSIS OF 155MM M483A1 PROJECTILE ACCURACY BASED ON 155MM M107 PROJECTILE REGISTRATIONS

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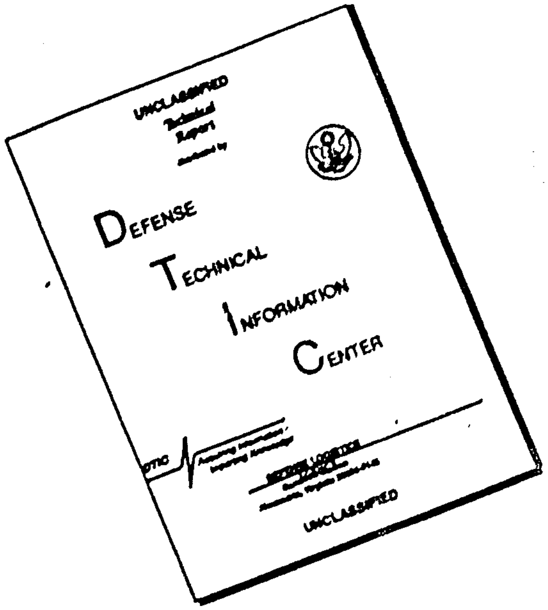

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Current Field Artillery doctrine requires that each family of projectiles, such as the 155mm M483A1 and 155mm M107 projectile families have its own registration. This requirement dictates the firing of many projectiles which is not only expensive, but it also takes time and, in combat, probably reduces the chances of survivability. By being able to conduct a registration with one type of projectile and having the firing data applicable to all projectiles of the same caliber, regardless of shape and ballistic similarity, these problems would be minimized. This report presents an analysis of a series of test firings, which was conducted at Ft. Sill, OK during the Fall of 1977, to ascertain the ability of the 155mm M107 projectile to be used as a registration (spotter) round for the 155mm M483A1 projectile.

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Analysis of 155mm M483A1 Projectile Accuracy
Based on 155mm M107 Projectile Registrations

1. SUMMARY

Current Field Artillery doctrine requires that each family of projectiles, such as the 155mm M483A1 and 155mm M107 projectile families, have its own registration. This requirement dictates the firing of many projectiles which is not only expensive, but it also takes time and, in combat, probably reduces the chances of survivability. By being able to conduct a registration with one type of projectile and having the firing data applicable to all projectiles of the same caliber, regardless of shape and ballistic similarity, these problems would be minimized. This report presents an analysis of a series of test firings, which was conducted at Ft. Sill, Oklahoma during the Fall of 1977, to ascertain the ability of the 155mm M107 projectile to be used as a registration (spotter) round for the 155mm M483A1 projectile.

The test program was conducted using five charges (Zone 3/M3A1, Zone 5/M3A1, Zone 5/M4A2, Zone 7/M4A2, and Zone 8/M119) fired at low angle and high angle from both new and worn M185 tubes. This report presents the results of the low angle firings from the new tube. The remaining data are being analyzed and will be published as an addendum to this report when the analysis is completed.

The M483A1 and M107 projectiles are, by definition, ballistically dissimilar: that is, they have different shapes, ballistic coefficients, projectile weights, muzzle velocity, etc. However, the effects of nonstandard conditions, such as muzzle velocity variation from standard (MVV), wind, air temperature and density, affect both projectiles in the same manner. Therefore, a M107 projectile registration could estimate the total effects of these nonstandard conditions for the M483A1 projectile.

Basically, the test consisted of firing three types of registrations and transfers.

a. MET+VE. A M107 ground burst mean point of impact (MPI) registration to estimate the M483A1 velocity error (VE). The remaining data needed to fire at the transfer targets were taken from the M483A1 firing table.

b. Addendum. A M107 high burst registration to estimate total range and fuze time corrections for the M483A1. An addendum was used to correct for the flight differences between the projectiles (i.e., quadrant elevation needed to fire the M483A1 to the same M107 range).

c. Self Registration. A M483A1 high burst registration conducted according to standard procedures. This phase was fired to provide a means for assessing the adequacy of the other two procedures.

For the first two methods, the M107 was also fired at the transfer targets to compare M107 accuracy to the M483A1 accuracy.

The M483A1 miss distances based on a M107 high burst registration (addendum method) are approximately the same as the M107 miss distances based on the same M107 high burst registration as shown below.

Projectile	Average Miss(M)	Standard Deviation(M)
M483A1	53	56.9
M107	34	61.6

Using a one to one correlation (i.e., the difference between the MPI's of the M483A1 and M107 when fired to the same target using data obtained from the same registration) the average difference was 19 meters (38.9 meter standard deviation), which is within one M107 Firing Table probable error.

The overall M483A1 miss distances using the addendum method is approximately the same as the M483A1 miss distances using the self registration method as shown below.

Method	Average Miss(M)	Standard Deviation(M)
Addendum	53	56.9
Self Registration	-25	51.3

In this regard, the M483A1 miss distance mean and standard deviations for the addendum method are slightly inflated due to velocity trends in the Zone 3 M3A1 charge. These affects are discussed later.

The MET+VE method provided good results in Zone 3 of the M3A1 charge, however, the mean and standard deviation of the miss distances for the other charges were much higher for both the M483A1 and M107 projectiles as evidenced by the following data:

	M483A1		M107		Difference (M483A1-M107)	
Zone/Charge	Mean Miss(M)	Std. Dev.(M)	Mean Miss(M)	Std. Dev.(M)	Mean(M)	Std. Dev.(M)
3/M3A1	34	56.6	45	59.3	-11	35.6
5/M3A1	137	90.4	76	79.0	61	52.2
5/M4A2	-73	182.4	-65	177.5	- 7	5.0
7/M4A2	114	99.8	7	81.7	107	50.8
Overall	68	105.5	36	87.6	29	61.2

With regard to the M483A1 results, it should be emphasized that the firing data used to compute the transfer aiming data were M107 VE plus met corrections obtained from the M483A1 firing table and the met message. With regard to the applied M107 VE, each M107 registration was followed by M483A1 projectiles fired for ground impact at the registration point (fired cold stick). Computing the VE fro… the M483A1 MPI, the difference

between the applied M107 VE and the computed M483A1 VE was 6 meters (31.8 meter standard deviation) for nine of the eleven events fired - two occasions discarded due to velocity trends and suspected gunner error. Therefore, the M107 VE is a good approximation for the M483A1 VE. That is, had the computed M483A1 VE been applied rather than the M107 VE, the results would have been the same. Thus, it appears that computing a high burst MET+VE transfer based on a ground impact registration may result in large miss distances for both the M483A1 and M107 at zones above Zone 3 of the M3A1 charge.

Due to the grooving in the forcing cone to prohibit projectile fallback in the M185 tube, the M107 velocities from this tube are different from the M107 firing table, which was based on the "ungrooved" version. BRL Firing Tables Branch provided estimates to adjust for this bias. The correction for Zone 8 M119 charge was based on very limited data and the results of this test were used to correct the estimated bias. As a result, the correction was found to be minus 10.8 meters per second which was significantly different from the original estimate. Because of this difference, the M119 charge firings had large miss distances which resulted in observation and firing problems. This also caused problems in analyzing the data.

Based on one days firing, after making corrections for the velocity bias, the results show that the M483A1 and M107 achieved the same miss distances for the MET+VE and addendum methods when firing the M119 charge as evidenced by the following data:

Transfer Method	M483A1 Mean Miss(M)	M107 Mean Miss(M)
MET+VE	123	127
Addendum	-42	-88
Self Registration	-57	

Also, the M483A1 mean miss distance for the addendum method is the same as it is for the M483A1 self registration method. The M483A1 and M107 mean miss distances for the MET+VE method are worse than the other methods which follows the observations made in the MET+VE discussion. Therefore, based on these limited data, the transfer methods under test should provide the same approximate accuracies for the M119 charge as that observed for the other charges.

Velocity trends during the test had a direct influence on the observed transfer accuracies for Zone 3 of the M3A1 charge and Zone 5 of the M4A2 charge.

For Zone 3, approximately 25 to 30 rounds were needed to be fired before the velocity level stabilized. Registrations conducted during the warming period almost always had a lower velocity than the transfer groups - velocity difference as high as 10 meters per second. As a result, the transfer missions always fired long, sometimes over 100 meters. This

velocity trend affects the M107 and M483A1 in the same manner. Because of this velocity trend the overall standard deviations in the MET+VE and Addendum transfers given above are slightly inflated. The self registration technique was always fired (one exception) from a conditioned tube, thus the self registration technique was not influenced by this velocity trend.

For Zone 5 of the M4A2 charge, tube memory apparently had an effect on the transfer missions for one days firings; that is, preceding this days' firing a Zone 8 M119 charge test phase was conducted. The following day when a Zone 5 M4A2 charge test phase was fired, the velocity level was approximately 7 meters per second above standard and decreased rapidly over the next 30 rounds. As a result, the transfers were extremely short of the target (200 meters). On another day following a Zone 3 M3A1 charge test phase, the velocity level was at standard and remained constant throughout the days' firing. The transfer mission for this day was very good (60 meters miss for the first occasion).

For all zones, except Zone 5 of the M3A1 charge, the M107 and M483A1 muzzle velocity variation from standard (MVV) were about the same. The Zone 5 M3A1 charge firings had an approximate 5 meter per second difference. Since the M483A1 velocities were close to standard and the M107 velocities were high, it is felt that the grooved tube velocity correction could be in error and should be reassessed. MVV's corrected for grooved tube velocity bias and powder temperature were used throughout this report.

2. CONCLUSIONS

From the results of this test program, several significant conclusions can be made.

a. M483A1 projectile transfer accuracy based on M107 projectile high burst registrations (the addendum technique) is virtually the same as M483A1 projectile transfer accuracy based on M483A1 projectile high burst registrations (self registration technique). Therefore, the M107 projectile can be used as a registration (spotter) projectile for the M483A1 projectile without any degradation in accuracy.

b. Using a ground impact MPI (mean point of impact) registration and the MET+VE transfer technique for computing high burst ICM type firing solutions may lead to large target miss distances, particularly at Zone 5 and up. These large miss distances occurred for both the M483A1 and M107 transfers using the same M107 registrations. Also, transferring the M483A1 using M483A1 MPI registration data and the MET+VE method would yield the same results as the M107 MPI registration did.

c. Comparing M107 transfer accuracies to M483A1 transfer accuracies, when the firing data were computed from the same M107 registration, shows that the M107 and M483A1 transfer accuracies are essentially the same. Therefore, if the M107 accuracy is considered acceptable then the M483A1 transfer accuracy using M107 registrations must also be considered acceptable.

d. For the lower zones (Zone 3 through 5), tube conditioning can greatly influence accuracy. Velocity variations from standard (MVV) may vary due to tube temperature, previous charges fired, propellant interaction, etc. Both the M107 and M483A1 projectile velocities are influenced in the same manner.

3. INTRODUCTION

Current doctrine dictates that firing data computations for the M483A1 DP ICM projectiles be determined in the self registration mode and that corrections be applied to fire the projectile in the ICM mode; i.e., the same procedure as used with the standard M107 projectile and the M449 family of AP ICM projectiles. A high-order detonation is achieved in the M483A1 self registration mode by removing the expulsion charge and installing a spotting or self registration charge onto the base of the M577 fuze. This procedure dictated that two registrations, one for M107 HE and the other for M483A1 DP ICM, had to be conducted. Registration with the M483A1 is very costly, not only in terms of money (the cost of a M483A1 projectile is several times more that of the M107 HE projectile), but also in terms of time and survivability (how many registrations can be afforded based on the enemy's target acquisition capability?). By being able to conduct a registration with one type of projectile and having the firing data applicable to all projectiles, regardless of shape and ballistic similarity, the above problems would be minimized.

During March 1975, an experiment was conducted at an OCONUS site to ascertain the ability of the M107 projectile to be used as a spotter or registration round for the M483 projectile. Although the experiment was limited in scope, the results indicated that such a solution was viable - range miss distances varied from 20 to 158 meters dependent upon charge. On 25 April 1977, Dr. Sperrazza, Director, US Army Materiel Systems Analysis Activity (USAMSAA), and MG Keith, Commandant, Field Artillery School (FAS), agreed that an operational test be conducted at Fort Sill to further investigate the procedures. AMSAA and the Gunnery Department, FAS, prepared a test plan which was conducted during 3 Oct through 14 Dec 1977 by the US Army Field Artillery Board.

4. PURPOSE

The purpose of this study is three fold: 1) to measure the accuracy of the M483A1 transfer based on M107 registration, 2) to compare the M483A1 transfer accuracy to M107 transfer accuracy when the firing (aiming) data were obtained from the same M107 registration, and 3) to compare the overall results of the M483A1 accuracies obtained from the M107 registrations to M483A1 accuracies obtained from M483A1 self registrations.

5. TEST METHODOLOGY

To obtain the necessary data to make these evaluations, the test firing included three types of registration and transfer missions.

MET+VE.

This technique involved a ground burst, mean-point-of-impact (MPI) registration using the M107 projectile with the M557 PD fuze. A concurrent met was solved using the M107 Tabular Firing Table (TFT) 155-AM-1 to isolate the M107 met and position corrections - position deflection corrections and position velocity error (VE). No time fuze correction was available from the MPI registration. The firing data for the M483A1 projectile were obtained by solving a subsequent met for the M483A1 using the 155-AM-1 TFT (M483A1 firing table) and adding the M107 position VE. The fuze settings were determined from the elevation plus comp site (burst height). Following the M483A1 projectile transfer mission, a M107 projectile mission was also fired at the same target. The firing data for the M107 were obtained directly from the M107 MPI registration.

Immediately following the M107 registration firings, a three round group of M483A1 projectiles were fired at the M107 registration aim point to provide met and VE estimates for the M483A1 for comparison purposes.

The second technique (hereafter referred to as the FT addendum technique), involved a high burst registration using the M107 HE projectile with either the M564 or M582 mechanical time fuze. Graphical Firing Table (GFT) registration corrections were determined and applied in the normal manner. Using the M483A1 fuzed with the M577 mechanical time fuze, transfer missions were fired by applying deflection, time and quadrant correction factors extracted from a trial firing table addendum (FT ADD), prepared by Ballistic Research Laboratories (BRL). Again both M107 and M483A1 four round transfers were fired at the same target.

The third technique (hereafter referred to as the self-registration technique), involved a high burst registration using the M483A1 projectile with the M577 fuze. Registration corrections were determined and applied in the normal manner and M483A1 transfers were fired.

Appendix B provides a detailed example of these procedures. Further explanations of the gunnery aspects may be obtained from FM6-40, Field Artillery Cannon Gunnery.

5.1 Conditions of Test.

The three registration and transfer techniques discussed above were each tested in the following phases;

Table 1

Test Conditions

Zone	Charge	Angle of Fire	Transfer Distance*
3	M3A1	Low	+430m, -790m
3	M3A1	High	+430m, -790m
5	M3A1	Low	+707m, -793m
5	M3A1	High	+707m, -793m
5	M4A2	Low	+1345m
7	M4A2	Low	-1169m
8	M119	Low	+1440m, -1130m
8	M119	High	+1440m, -1130m

*The signs indicate the target location with respect to the registration aiming point.

Each charge, angle of fire, and indicated transfers were fired on three separate occasions (replications) from a new M185 cannon. On two occasions, the M107 projectile fired for air burst was fuzed with the M564 MTSQ fuze. On the third occasion, it was fuzed with the M582 MT fuze. The M582 MT fuze is identical to the M577 MT fuze except that it has a booster cup (deep intrusion) for compatibility with the M107 projectile. One additional replication was performed from a worn (25 percent life remaining) M185 cannon - M107 fuzed with M564 MTSQ fuze.

MET+VE and addendum techniques were alternated in their order of fire. Overall, a total of 985 M107 projectiles and 923 M483A1 projectiles were fired.

5.2 Data Collection.

a. Muzzle velocity was measured by a DR 810 velocimeter and was backed up by a M36 chronograph.

b. Fuze burst times were measured by infra-red (BTI) backed up by a stop watch.

c. Impact points were obtained by sightings from four observers.

d. The fire direction center (FDC) was composed of personnel from the gunnery department. All FDC computation sheets were made available after each day's firing.

e. Other data collected included powder temperature at 15 minute intervals, meteorological readings every two hours, time of fire, ammunition lot numbers, and FADAC range data which were verified by a Wang 2200 VP Computer.

6. DISCUSSION OF TEST RESULTS

6.1 General.

a. The discussion of the test results will include several topics.

1) An analysis of each transfer method followed by an overall assessment.

2) Analysis of the M107 projectile with the M582 fuze test firings.

3) Discussion of the Zone 8/M119 charge test firings.

4) Analysis of velocity and its effect on delivery accuracy.

b. To support the above discussions, several appendices are provided which offer detailed explanations and/or background information relative to the discussions. These appendices discuss topics concerning discarded observations, M107 projectile firing table velocity bias, test biases, historical data on velocity trends, and an overall summary of the test data. There are also detailed examples of the Fire Direction Center (FDC) procedures for computing firing data for each transfer method. It is recommended that the reader become familiar with the appendices as they are continually referenced throughout the discussion.

c. The basic data for the analysis are contained in Table 2. For each firing occasion, the table shows the miss distances observed for each transfer. Each occasion represents one day's firing. For the MET+VE and Addendum techniques, the respective M483A1 and M107 transfers were fired using data obtained from the same M107 registration - a M107 ground burst MPI registration was used for the MET+VE technique and a M107 high burst registration was used for the addendum technique. The numbers in parentheses are miss distances corrected for observer or FDC errors (Appendix A).

As discussed in Appendix A, the M107 grooved tube velocity bias had an effect on the M483A1 transfers, particularly for the MET+VE technique where the correction for this bias was not made. The firing table addendum used in the addendum technique accounted for the correction. Table 3 presents these data corrected for grooved tube velocity.

Table 2

Comparative Miss Distances (Range in meters)

Zone/ Charge	Occasion	Range	Transfer Method: MET+ VE M483A1	Transfer Method: MET+ VE M107	Transfer Method: Addendum M483A1	Transfer Method: Addendum M107	Transfer Method: SR[a] M483A1
3/M3A1	1	5300	80	129(81)[e]	45	28	-63
		4080	123	136	20	0	-25
	2	5300	- 44	- 31	77	93	-10
		4080	- 19	17	120	103	-37
	3	5300	- 30	- 19	91	18	-128
		4080	11	30	66	-20	-109
	4[b]	5300	- 5	109	44	-12	-73
		4080	15	39	65	111	5
5/M3A1	1	8227	- 12	7	- 86	-35	-16
		5570	122	26	4	-41	24
	2	8207	130	--[c]	141	140	2
		6710	111(128)[e]	41	103	80(111)[e]	28
	3[b]	8207	246[d]	201	1	-10	-56
		6710	185	145(105)[e]	-42	-61	-14
5/M4A2	1	8661	- 52	60[d]	68	47	-78
	2[b]	8661	- 310	-191	35	- 3	-22
7/M4A2	1	9421	- 62(-83)[e]	- 60	59	- 1	-21
	2	9421	154(60)[f]	- 17	128	73	25
	3[b]	9421	109	98	69	77(104)[e]	86

a) M483A1 Self Registration

b) M107 fuzed with M582 MT Fuze

c) Data discarded due to fuze malfunctions and observer error.

d) FADAC and Wang Range Computer data not available. Estimated from Test Officer's daily record.

e) Observer Error. ( ) indicates corrected range.

f) FDC error. Calculated subsequent met on wrong met line.

Table 3

Comparative Miss Distances (Range in meters)
(M483A1 Corrected for Grooved Tube Velocity)

Zone/ Charge	Occasion	Range	Transfer Method				
			MET+VE		Addendum		SR
			M483A1	M107	M483A1	M107	M483A1
3/M3A1	1	5300	100	81	45	28	- 63
		4080	139	136	20	0	- 25
	2	5300	- 24	- 31	77	93	- 10
		4080	- 3	17	120	103	- 37
	3	5300	- 10	- 19	91	18	-128
		4080	27	30	66	- 20	-109
	4	5300	15	109	44	- 12	- 73
		4080	31	39	65	111	5
5/M3A1	1	8227	- 19	7	- 86	- 35	- 16
		5570	127	26	4	- 41	24
	2	8207	137	--	141	140	2
		6710	134	41	103	111	28
	3	8207	253	201	1	- 10	- 56
		6710	191	105	- 42	- 61	- 14
5/M4A2	1	8661	56	60	68	47	- 78
	2	8661	-202	-191	35	- 3	- 22
7/M4A2	1	9421	2	- 60	59	- 1	- 21
	2	9421	145	- 17	128	73	25
	3	9421	194	98	69	104	86

d. The analysis performed in this report is concerned only with range component errors. Deflection component errors are affected by crosswind and drift. Also, these influences affect both the M107 and M483A1 projectiles with the same order of magnitude. For example, Table 7 gives deflection misses for the M107 MPI registrations and M483A1 check rounds fired during the MET+VE test phases. For all of these events, the mean difference between the M483A1 and M107 deflection components was -2 meters (15.1 meter standard deviation). Therefore, deflection errors are not considered significant enough to be included in the analysis of the transfer methods.

6.2 Analysis of the MET+VE Technique.

a. As previously discussed (paragraph 4.1), the M483A1 transfer aiming data were computed using the VE obtained from a M107 MPI registration and subsequent MET corrections obtained from the M483A1 firing table. In order to verify that the M107 VE is a good approximation for the M483A1, a three round group of M483A1 projectiles was fired for ground impact at the M107 registration point (cold stick) following the M107 MPI registration. By computing the M483A1 VE from the M483A1 MPI (check rounds), a comparison could then be made to the applied M107 VE. Table 4 presents the M107 applied (observed) VEs for each M107 MPI registration (expressed in meters) and the M483A1 VEs computed from the M483A1 check round MPI. The M107 VEs that were applied to the M483A1 did not include the grooved tube velocity correction. The corrected VEs are given in Table 4 (i.e., the VE that would have been applied to the M483A1 had the velocity correction been made) - the grooved tube velocity difference is discussed in Appendix A.

From Table 4, it can be seen that the M107 VEs (corrected) and the M483A1 VEs agree with one another rather well for nine of the eleven occasions. The mean difference between the two was 6 meters (31.8 meter standard deviation). Therefore, the M107 VE is a good approximation to the M483A1 VE. For the two occasions where a large difference is observed, one (occasion 1, Zone 3/M3A1) is due to an abnormal velocity trend (para. 5.6) and the other is due to a suspected error in the M483A1 check round firings.

b. From the data summarized in Table 5, it is evident that the M483A1 miss distances are quite good for the MET+VE technique (M107 registration) when firing the M3A1 charge in Zone 3. Generally, the miss distances were within one firing table probable error. For the other zones, M483A1 miss distances of over 100 meters were very common - in fact they were the rule rather than the exception. However, the M107 MET+VE transfers using M107 registration data performed only slightly better overall, dependent upon charge. That is, from Table 5 it is evident that the M483A1 and M107 miss distances were approximately the same for Zone 3 of the M3A1 charge and Zone 5 of the M4A2 charge whereas for the other charges the M483A1 consistently fired longer than the M107.

Table 4
M107 vs M483A1
Computed Velocity Error (VE)
(VE Expressed in Range-Meters)

Zone/ Charge	Occasion	Velocity Error (VE) M107 Observed	Velocity Error (VE) M107 Corrected*	M483A1
Zone 3/M3A1	1	-115	[illegible]	22
	3	47	29	44
	4	77	59	87
Zone 5/M3A1	1	38	33	22
	2	-134	-139	-114
	3	- 17	- 22	- 47
Zone 5/M4A2	1	62	- 24	- 23
	2	255	169	114
Zone 7/M4A2	1	99	13	44
	2	64	- 22	23
	3	- 86	-172	39

*Corrected for grooved tube velocity.

Table 5
MET+VE Transfer Miss Distance (Meters)
Corrected for Grooved Tube Velocity

Zone/ Charge	Occasion	M483A1 Observed	M483A1 Corrected	M107 Observed	Difference
Zone 3/M3A1	1	80	100	81	19
		123	139	136	3
	2	- 44	- 24	- 31	7
		- 19	- 3	17	- 20
	3	- 30	- 10	- 19	9
		11	27	30	- 3
	4	- 5	15	109	- 94
		15	31	39	- 8
Zone 5/M3A1	1	- 12	- 19	7	- 26
		122	127	26	101
	2	130	137	--	--
		128	134	41	93
	3	246	253	201	52
		185	191	105	86
Zone 5/M4A2	1	- 52	56	60	- 4
	2	-310	-202	-191	- 11
Zone 7/M4A2	1	- 83	2	- 60	62
	2	60	145	- 17	162
	3	109	194	98	96

Looking at the data from Table 5 a little differently, the mean miss distance and the standard deviation of that difference for each charge are shown in Table 6.

Table 6

M483A1 and M107 Transfer Accuracies
for the MET&VE Technique
(Range Miss-Meters)

	M483A1				M107		Difference	
Zone/	Observed		Corrected		Observed		Corr. M483A1-M107	
Charge	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
3/M3A1	16.4	57.26	34.4	56.65	45.2	59.27	-10.9	35.58
5/M3A1	133.2	85.62	137.2	90.35	76.0	78.98	61.2	52.20
5/M4A2	-181.0	182.43	-73.0	182.43	-65.5	177.48	- 7.5	4.95
7/M4A2	28.7	99.76	113.7	99.76	7.0	81.69	106.7	50.85
Overall	34.4	121.75	68.1	105.51	36.2	87.65	29.1	61.18

While the mean distance between the M483A1 and M107 are different in Zone 5, M3A1 charge and Zone 7, M4A2 charge, the standard deviation of these miss distances (i.e., the occasion-to-occasion difference of the mean points of impact) for each projectile for each charge are not different. Considering the difference in the lethality of the M483A1 as opposed to the M107, if the MET+VE technique is considered an acceptable technique of fire for the M107 projectile, then this same technique for the M483A1 using M107 registration data must also be considered acceptable based on the results of this study.

c. It was shown in paragraph a. above that the M107 VEs and the M483A1 VEs are about the same. It is also apparent that using the M483A1 check round MPI as a registration for the M483A1 MET+VE transfers would have yielded approximately the same results. Considering the magnitude of the M483A1 miss distances for Zone 5 of the M3A1 charge and Zone 7 of the M4A2 charge, there appears to be an error inherent to the procedure of computing high burst transfer aiming data from a ground impact MPI registration. It appears that the same conclusion holds true for the M107, but to a lesser extent. There are not sufficient data at this time to fully understand this phenomenon - in that it appears to be charge related, but with the small number of occasions involved, it may be due to chance or unaccountable field conditions. In any event, it should be emphasized that using either a M107 or M483A1 MPI ground impact registration would yield approximately the same M483A1 transfer accuracy firing in the ICM mode.

d. The FDC procedure for the MET+VE technique used in this test required that the FDC compute met effects for both the M107 and M483A1 projectiles. Not only is this procedure time consuming, it also increases the chances of computational error. By applying the total M107 corrections directly to the M483A1 with adjustments for range,

deflection, and fuze time due to the basic differences between the two projectiles (i.e., firing table addendum), these problems would be minimized. Table 7 provides the M107 registration and M483A1 check round MPI results and the corrections computed by the FDC. From this table, it is evident that the overall corrections for nonstandard conditions between the rounds are very close. The average difference in met corrections was a minus 2 meters (18.3 meter standard deviation) and the average difference in powder temperature corrections was 8 meters (6.0 meter standard deviation). In considering the total accuracy, these differences are negligible.

Table 7

Comparative MPI and MET Data for the M107 and M483A1 Projectiles from the MET+VE Technique

Zone/ Charge	Occasion	MPI Miss (meters)				MET[a](m)		Powd Temp[b](m)		Proj. Wgt[c](m)		VE (m)[d]	
		Range		Deflection									
		M107	M483	M107	M483	M107	M483	M107	M483	M107	M483	M107	M483
3/M3A1	1	-117	- 19	139	146	24	8	- 26	- 13	----	- 36	-115	22
	2	119	61	48	51	--[e]	--	--	--		--	---	--
	3	- 9	- 59	45	56	- 6	- 31	- 50	- 34	----	- 38	47	44
	4[f]	85	36	165	160	11	- 10	- 3	- 3	----	- 38	77	87
5/M3A1	1	17	- 35	70	71	- 7	- 21	- 14	- 12	----	- 24	38	22
	2	- 63	- 91	94	100	95	67	- 24	- 20	----	- 24	-134	-114
	3[f]	-120	-161	24	30	- 67	- 60	- 36	- 30	----	- 24	- 17	- 47
5/M4A2	1	49	- 3	- 62	- 60	17	18	- 30	- 27	----	- 17	62	- 23
	2[f]	172	34	62	28	- 39	- 28	- 44	- 35	----	- 17	255	114
7/M4A2	1	31	10	56	30	20	55	- 88	- 75	----	- 14	99	44
	2	-314	-341	- 78	- 60	-258	-247	-120	-102	----	- 15	64	23
	3[f]	166	288	- 12	- 22	292	295	- 40	- 32	----	- 14	- 86	39

a) Meteorological influence on range

b) Effect on range due to powder temperature

c) M483A1 was weight Zone 5 where Zone 4 is standard

d) Velocity error or remaining unaccountable error expressed in range

e) FDC data were not available.

f) M107 Projectile fuzed with M582 MT Fuze.

6.3 Analysis of the Addendum Technique.

a. This transfer method employs a M107 high burst registration from which total range, deflection, and fuze time corrections are determined. These corrections are applied directly to the M483A1 with adjustments for quadrant elevation (QE), deflection, and fuze time to achieve the M107 range. These adjustments are provided in a firing table addendum prepared by the BRL Firing Tables Branch. The addendum also corrected for the grooved tube velocity bias.

b. Returning to Table 2, it can be seen that for most occasions the M483A1 and M107 projectile miss distances for the addendum technique are of the same order of magnitude. Moreover, the overall difference of 19 meters, as shown in Table 8, is within one firing table probable error. Also, from Table 8, the overall means and standard deviations of the miss distances for the M483A1 and M107 projectiles are very close. Therefore, a M107 high burst registration is just as valid for the M483A1 projectile as it is for the M107 projectile. Moreover, if the M107 accuracies observed in this test for the addendum technique are considered acceptable, then the M483A1 accuracies must also be considered acceptable.

c. In Table 8, it is interesting to note that the standard deviations for both the M483A1 and M107 projectiles are higher for Zone 5 of the M3A1 charge than the other charges. These standard deviations approximate those observed in the MET+VE technique for this charge (Table 6), but the means for the addendum method are much closer to the target (both within one probable error). Looking at the actual miss distances for this charge in Table 2, the miss distances for both the M483A1 and M107 were relatively close to the target for occasions 1 and 3 (average -31 meters for M483A1 and -37 meters for M107), whereas the miss distances for occasion 2 were much longer (over 100 meters). Also the M483A1 and M107 miss distances for this occasion are the same. Since the M107 has been a standard projectile and used in training for over thirty years, the delivery procedures (gunnery solutions) should be well known and acceptable. Therefore, miss distances such as those observed for occasion 2 of the Zone 5 M3A1 charge are probably due to chance. When making an evaluation for adequate accuracy of a system (like the M483A1), one must be cognizant of the fact that for small sample sizes an observation such as this inflates the standard deviation. In this test, M107 transfers using the addendum technique resulted in miss distances of over 100 meters in three out of nineteen occasions for which there are no physical explanation - such as velocity trends or obvious FDC errors (e.g., occasion 2 Zone 5/M3A1 charge and occasion 3 Zone 7/M4A2 charge). In the self registration method, two transfers for occasion 3 of the Zone 3/M3A1 charge had miss distances of over 100 meters.

Table 8

M483A1 and M107 Transfer Accuracies for the Addendum Technique
(Range Miss Distances-Meters)

Zone/ Charge	M483A1 Mean	M483A1 Std. Dev.	M107 Mean	M107 Std. Dev.	Difference (M483A1-M107) Mean	Difference (M483A1-M107) Std. Dev.
3/M3A1	66	30.9	40	53.9	26	44.5
5/M3A1	20	86.3	17	85.8	3	32.0
5/M4A2	51	23.3	22	35.4	29	12.0
7/M4A2	85	37.4	59	53.9	26	53.5
Overall	53	56.9	34	61.6	19	38.9

6.4 Comparison of Transfer Methods.

a. The M483A1 self registration phase was conducted to provide a means for assessing the adequacy of the other transfer methods. The individual miss distances are given in Table 3. By comparing the means and standard deviations of the three transfer methods as shown in Table 9, it can be seen that there is very little difference between the overall results of the M483A1 miss distances using the addendum technique and the M483A1 with the self registration method. As would be expected, based on the MET+VE discussion, the MET+VE technique did not perform as well as either the addendum or the self registration transfers. It should be noted that the means and standard deviations for both the MET+VE and addendum methods are inflated due to velocity trends in the lower zones - these effects are discussed in greater detail in paragraph 6.6. Due to the test bias discussed in Appendix A, the M483A1 self registration means and standard deviations do not include the magnitude of the velocity trends experienced by the other two methods. Taking these facts into consideration, it is felt that there is no difference between the addendum and self registration techniques when fired under identical conditions. Therefore, the M107 projectile can be used as registration round for the M483A1 using the addendum technique without any degradation in accuracy.

Using the M107 in an MPI registration (ground impact) is as good as using the M483A1 in an MPI registration to obtain aiming data for the M483A1 in a MET+VE transfer. However, because of apparent inherent errors in computing high burst aiming data from a ground impact registration, a degradation in accuracy can be expected for both the M483A1 and M107 projectiles at zones above Zone 3 of the M3A1 charge.

b. From Table 3, it is interesting to note that the M483A1 using the MET+VE and addendum techniques consistently fired over (long) the target whereas the M483A1 with the self registration technique consistently fired short of the target. This phenomenon had no resultant effect on the techniques accuracy (i.e., the mean MPI's were either short or long of the target within the same order of magnitude). If these observations were characteristic of the projectiles, it should be possible to build a minor correction (2 or 3 mils in elevation) into the firing table addendum, or provide an offset aiming procedure for the FDC, so that the mean MPI's could be closer to the target aim point. These corrections should be applicable to both the addendum (negative correction) and self registration techniques (positive correction).

Table 9

Comparison of Accuracy Between Transfer Methods
(Range Miss Distances-Meters)

Zone/ Charge	Transfer Method: MET+VE, M483A1 Corrected* Mean	S.D.	MET+VE, M107 Mean	S.D.	Addendum, M483A1 Mean	S. D.	Addendum, M107 Mean	S.D.	M483A1 Self Registration Mean	S.D.
3/M3A1	34	56.6	51	65.5	66	30.9	40	53.9	-55	47.0
5/M3A1	137	90.4	64	76.8	20	86.3	17	85.8	- 5	30.9
5/M4A2	- 73	182.4	-65	177.5	51	23.3	22	35.4	-50	39.6
7/M4A2	114	99.8	7	81.7	85	37.3	59	53.9	30	53.7
Overall	68	105.5	38	88.4	53	56.9	34	61.6	-25	51.3

*Corrected for grooved tube velocity.

6.5 M107 with M582 MT Fuze.

a. The M582 MT Fuze is the same as the M577 MT Fuze except that it has a booster cup for compatibility with the M107 projectile. The M564 MTSQ fuze is the current standard time fuze for the M107. The older generation mechanical time fuzes such as the M520A1, M500 series, and including the M564, have a fuze time bias (i.e., difference of average fuze functioning time from set time). These biases differ from fuze type to fuze type, with time setting and charge - the firing tables adjust for this bias.

b. The M582 fuze correction for the M564 fuze time bias is given in Appendix E. Generally, for these test conditions evaluated in this report (low angle fire), the M564 fuze time bias corrections were 0.1 or 0.2 seconds for Zone 3 of the M3A1 charge, 0.1 or 0.2 seconds for Zone 5 of the M3A1 charge, 0.1 seconds for Zone 5 M4A2 charge, and minus 0.2 seconds for Zone 7 M4A2 charge. By looking at the actual burst time in Table 10 (difference between burst time and set time), it can be seen that the burst times for all three fuzes are very close to set time, except for Zone 7 M4A2 charge where the M564 mean functioning time and standard deviation were slightly larger than for the other charges. Although there is a difference between the M564 fuze time correction and the M564 mean burst time, the difference is so small that any effect on accuracy would be negligible. For example, Zone 5 M4A2 charge requires that 0.1 seconds be added to the M577 fuze to account for the M564 fuze bias (built into the firing table addendum). Considering that if the M564 fuze burst at the set time (zero bias), the M577 fuze setting was in error by 0.1 seconds. The total effect on range was less than 10 meters.

c. The primary purpose of this test was to determine if M107 projectile high burst registrations with the M582 fuze could provide better aiming data than the M107 with the M564 fuze for the M483A1. From Table 11, it can be seen that the M483A1 transfers using the addendum method were better when the M582 fuze was used with the M107 projectile in the high burst registrations as compared to those conducted with the M564 fuze. On the other hand, the M107 with M582 fuze transfers based on M107/M582 fuze registrations were about the same as the M107/M564 projectile-fuze combination. Since the M107/ M582 fuze phase was conducted only once per charge (6 transfers total), the M483A1 difference may be due to chance. Therefore, in view of the actual fuze performance (burst times), the M107 accuracies in Table 11 and the overall analysis discussed in paragraph 6.4, there are insufficient data to conclude whether or not the M582 fuze is better than the M564 fuze in obtaining M107 registration data for application to the M483A1.

Table 10

Summary of Fuze Functioning
Occasion-to-Occasion
(Seconds)

Zone/ Charge	Fuze Type					
	M577		M564		M582	
	Average* Miss	Standard Deviation	Average* Miss	Standard Deviation	Average* Miss	Standard Deviation
3/M3A1	-.07	.08	0	.08	.05	.06
5/M3A1	-.03	.07	-.05	.09	-.05	.07
5/M4A2	0	.07	0	.14	.05	.07
7/M4A2	-.03	.05	-.25	.42	.05	.07

*Difference between set time and functioning time.

Table 11

M564 Fuze vs M582 Fuze
for M107 Projectile Registrations
(Accuracy Comparisons using the Addendum Method)

Projectile	Projectile/Fuze Combination*			
	M107 w/M564		M107 w/M582	
	Average Miss (m)	Standard Deviation	Average Miss (m)	Standard Deviation
M483A1	64	60.6	29	42.4
M107	39	59.7	21	69.8

*Registration posture.

6.6 Velocity Trends and Their Effect on Delivery Accuracy.

a. Throughout the discussion thus far, inferences have been made concerning accuracy errors caused by velocity variation due to unconditioned tubes and extraneous influences. There were several occasions in this test where definite velocity trends were observed which, at times, had a drastic influence on the transfer accuracies. For the most part, these velocity trends were charge related. (Appendix B discusses the nature of velocity trends and other such factors that could play an influential role in determining velocity errors and the accuracy of the various firing techniques.)

b. Figures 1 through 10 provide round by round plots of the muzzle velocity variation from standard (MVV) for both the M483A1 and M107 projectiles for each charge fired, including Zone 8/M119 charge. The MVV was corrected for powder temperature, projectile weight (M483A1 was weight Zone 5) and grooved tube velocity bias. These figures also give the miss distances (Rm) for each group, previous day fired, and previous charge fired.

As evidenced from these graphs, the Zone 3/M3A1 charge and Zone 5/M4A2 charges required several rounds to be fired before the velocity stabilized. The velocities for the remaining charges appear to have stabilized very quickly. From these graphs several observations can be made:

1) For Zone 3/M3A1 charge, there appears to be a common velocity trend from day to day (and tube to tube). The magnitude of this trend, however, fluctuates from day to day and there appears to be no commonality between two days firings for a given tube. For example, Figure 1 shows a drastic velocity variation for the first 25 rounds fired. This tube was used the following day for a Zone 3/M3A1 charge high angle test and the MVV plot approximated that of Figure 2. One possible explanation is that the Figure 1 firings occurred on a Monday and the tube had several days rest whereas the other two occasions were preceded the previous day by a test group.

Velocity data for occasion 1 Zone 3/M3A1 charge (Table 2) was not available, therefore, no velocity trend analysis can be made. However, by noting that this occasion was the first event of the test and was conducted on a Monday, as was the event presented in Figure 1, and also noting that the results of the transfer firings are approximately the same, it is suspected that an abnormal velocity trend influenced the results.

It is also interesting to note that for Figure 3, a 4.5 hour delay occurred during the day's firing due to weapon failure. Upon resuming the test with the M483A1 self registration phase, the velocity trend approximates that observed for the M107 at the beginning of the day. Therefore, this provides evidence that an unconditioned tube affects both the M107 and M483A1 velocities in much the same manner.

In any event, it appears that approximately 25 to 30 rounds need to be fired before the velocity stabilizes for this charge. If a registration is conducted during the conditioning period, inaccurate transfers may occur.

2) For the Zone 5/M4A2 charge, Figures 6 and 7 show a significant difference between the MVV levels for the two days firing. Noting that the previous day's firing for Figure 7 was a Zone 8/M119 charge test and the previous day for Figure 6 was a Zone 3/M3A1 charge test, it is suspected that tube memory influenced the velocity trend of Figure 7. As discussed in Appendix B, it is not unusual to have such a trend when firing a charge that was preceded by a higher charge. This trend, however, does not always occur for every charge as evidenced by the Zone 5/M3A1 charge firings (Figures 4 and 5). As an example, the test preceding that of Figure 4 was a Zone 3/M3A1 charge test and the test preceding Figure 5 was a Zone 8/M119 charge test. The velocity trends for these two Figures are approximately the same.

c. In regard to the Zone 5/M3A1 charge firings, there is approximately 5 meters per second difference between the MVV levels for the M107 and M483A1 projectiles. For all the other charges fired, including Zone 8/M119, the MVV levels for the two projectiles are approximately the same - when corrected for the grooved tube velocity bias. Since it was shown in Table 5 of the MET+VE discussion that the VE for these two rounds are approximately the same for the Zone 5/M3A1 charge, the MVV levels should also be the same. Therefore, it is felt that the Zone 5/M3A1 grooved tube velocity correction of 0.3 m/s could be in error and should be reassessed.

FIGURE 1

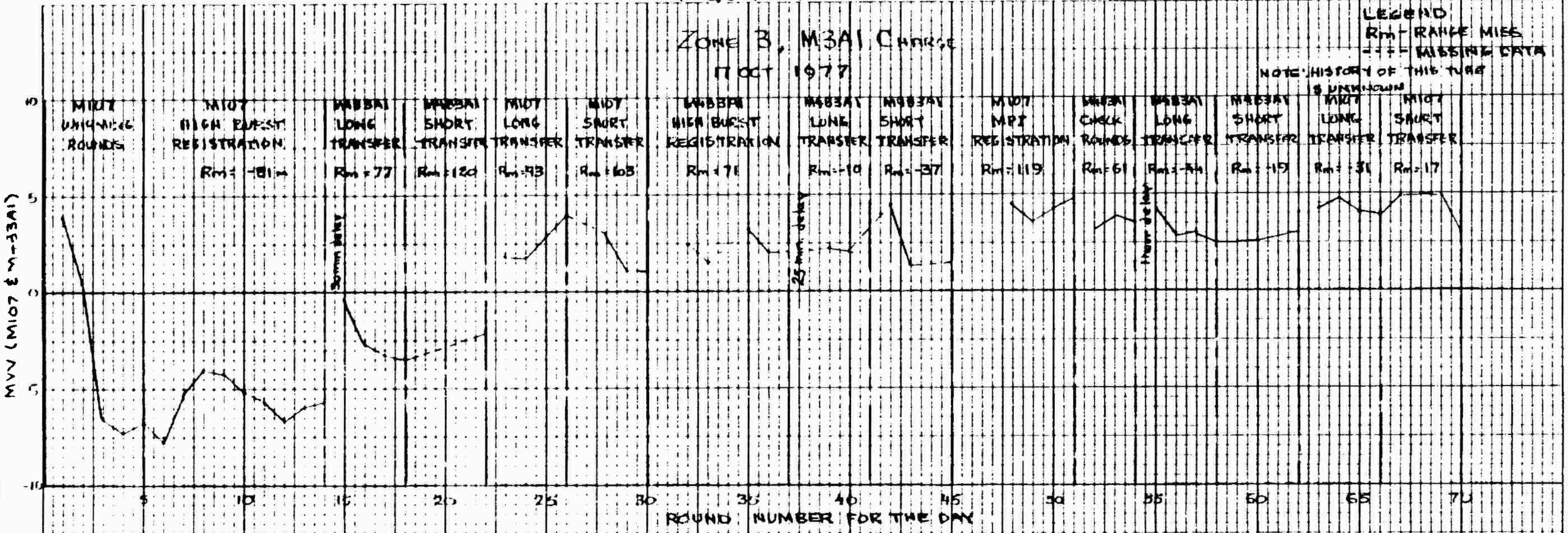


FIGURE 2 26 Oct 1977

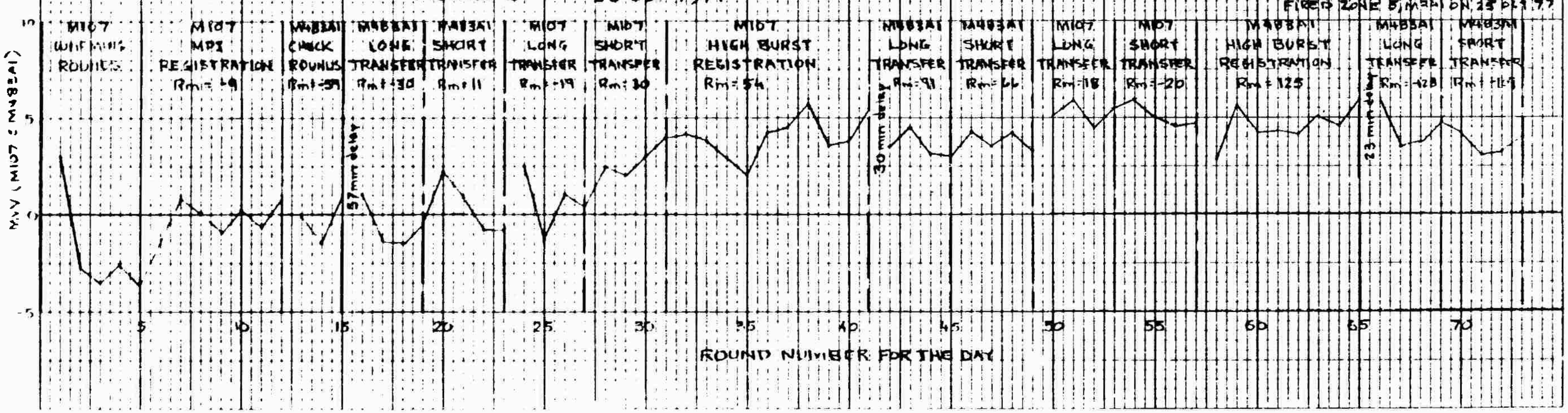


FIGURE 3

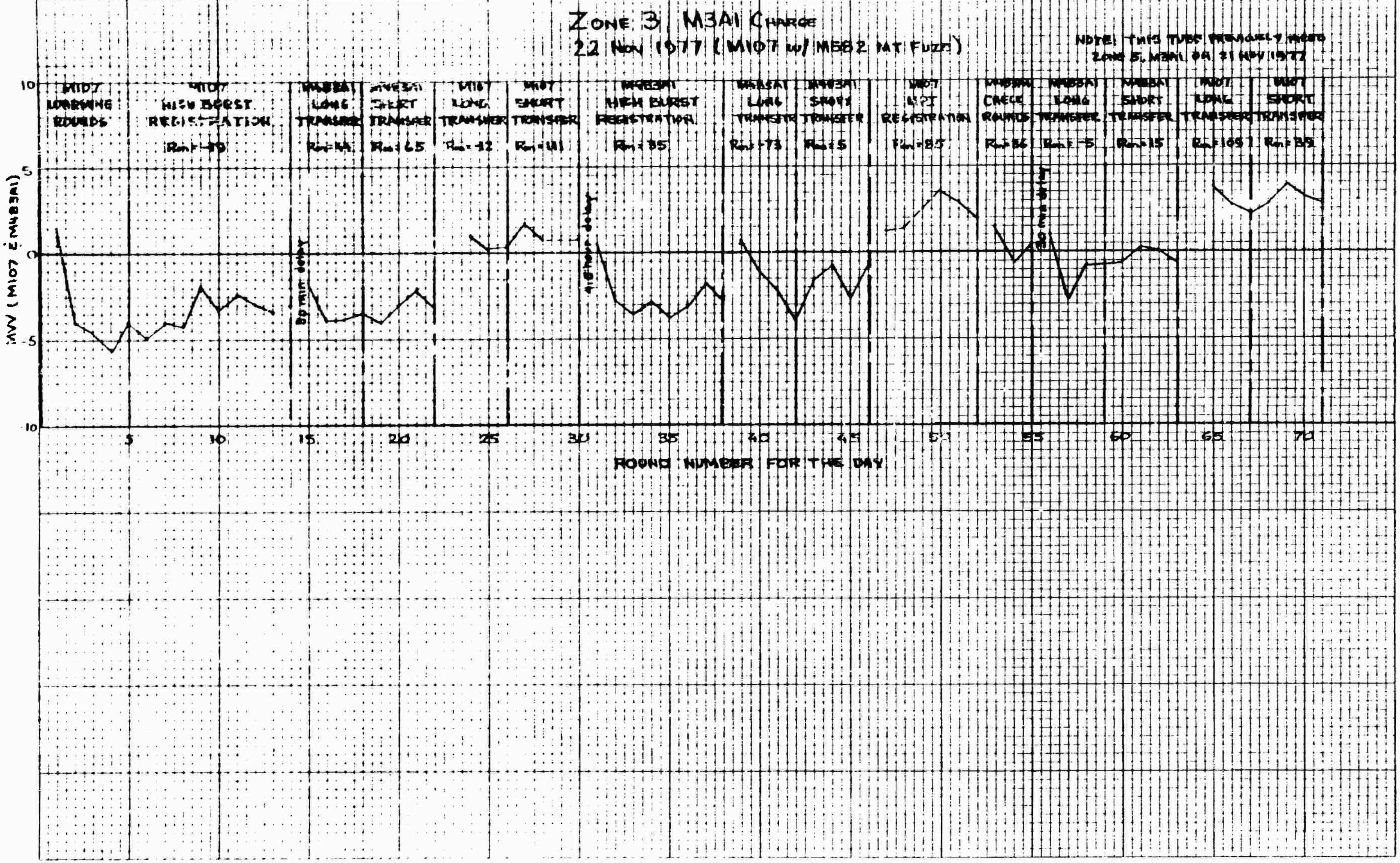
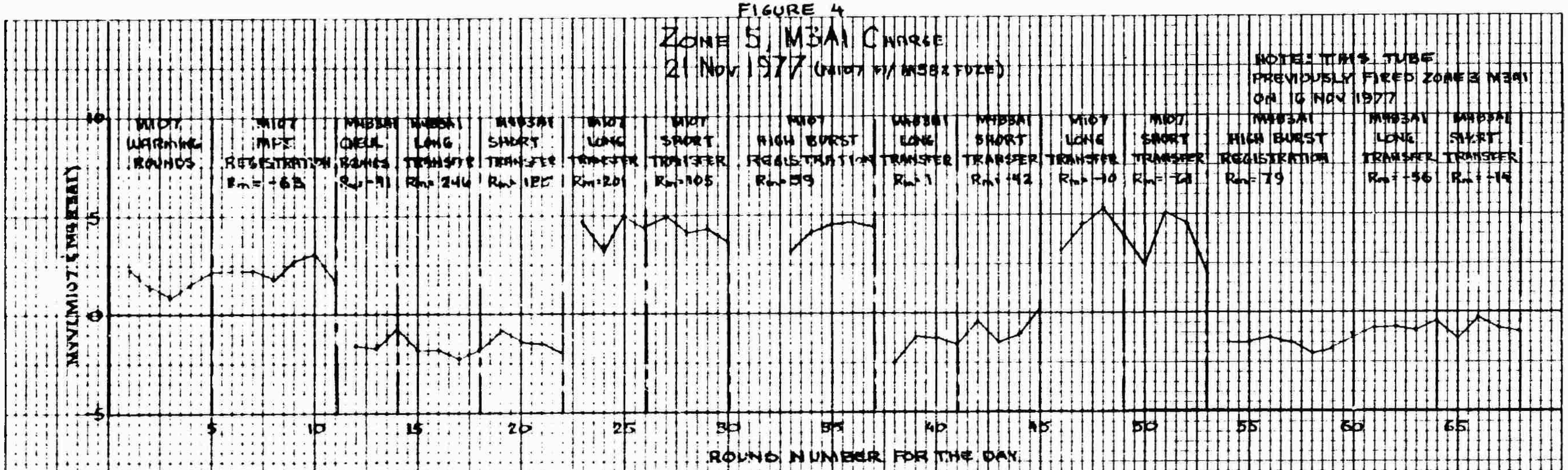

ZONE 3 M3A1 CHARGE
22 NOV 1977 (M107 w/ M582 MT FUZE)
M107 WARMING ROUNDS
M107 HIGH BURST REGISTRATION
LONG TRANSFER
SHORT TRANSFER
M483A1 HIGH BURST REGISTRATION
CHECK ROUNDS
ROUND NUMBER FOR THE DAY
MVV (M107 & M483A1)

FIGURE 4


ZONE 5, M3A1 CHARGE
21 NOV 1977 (M107 W/ M582 FUZE)
NOTE: THIS TUBE PREVIOUSLY FIRED ZONE 3 M3A1 ON 16 NOV 1977
M107 WARMING ROUNDS
M107 MPI REGISTRATION Rm = +63
M483A1 CHECK ROUNDS Rm = -91
M483A1 LONG TRANSFER Rm = 246
M483A1 SHORT TRANSFER
M107 LONG TRANSFER Rm = 201
M107 SHORT TRANSFER Rm = 105
M107 HIGH BURST REGISTRATION Rm = 59
M483A1 LONG TRANSFER Rm = 1
M483A1 SHORT TRANSFER Rm = 42
M107 LONG TRANSFER
M107 SHORT TRANSFER
M483A1 HIGH BURST REGISTRATION Rm = 79
M483A1 LONG TRANSFER Rm = 56
M483A1 SHORT TRANSFER
MVV (M107 & M483A1)
ROUND NUMBER FOR THE DAY

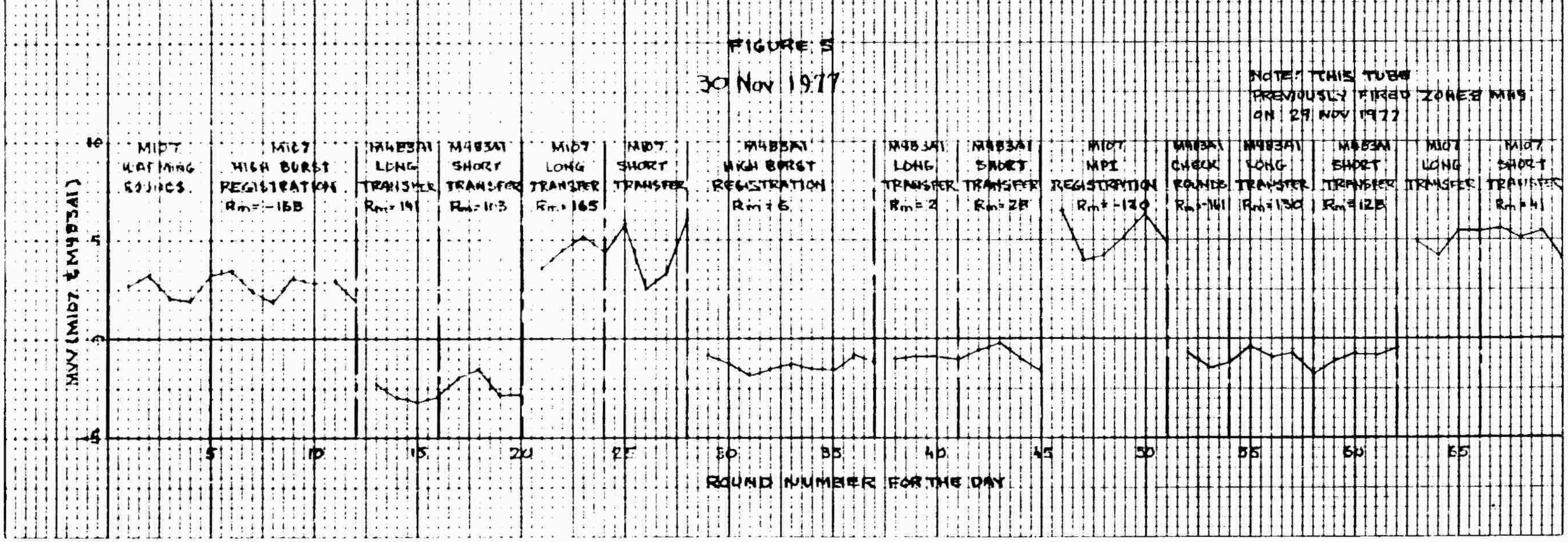


FIGURE 5
30 NOV 1977
NOTE: THIS TUBE PREVIOUSLY FIRED ZONE 2 M119 ON 29 NOV 1977
M107 WARMING ROUNDS
M107 HIGH BURST REGISTRATION Rm = -168
M483A1 LONG TRANSFER Rm = 191
M483A1 SHORT TRANSFER Rm = 113
M107 LONG TRANSFER Rm = 165
M107 SHORT TRANSFER
M483A1 HIGH BURST REGISTRATION Rm = 6
M483A1 LONG TRANSFER Rm = 2
M483A1 SHORT TRANSFER Rm = 28
M107 MPI REGISTRATION Rm = -120
M483A1 CHECK ROUNDS Rm = 141
M483A1 LONG TRANSFER Rm = 130
M483A1 SHORT TRANSFER Rm = 128
M107 LONG TRANSFER
M107 SHORT TRANSFER Rm = 41
MVV (M107 & M483A1)
ROUND NUMBER FOR THE DAY

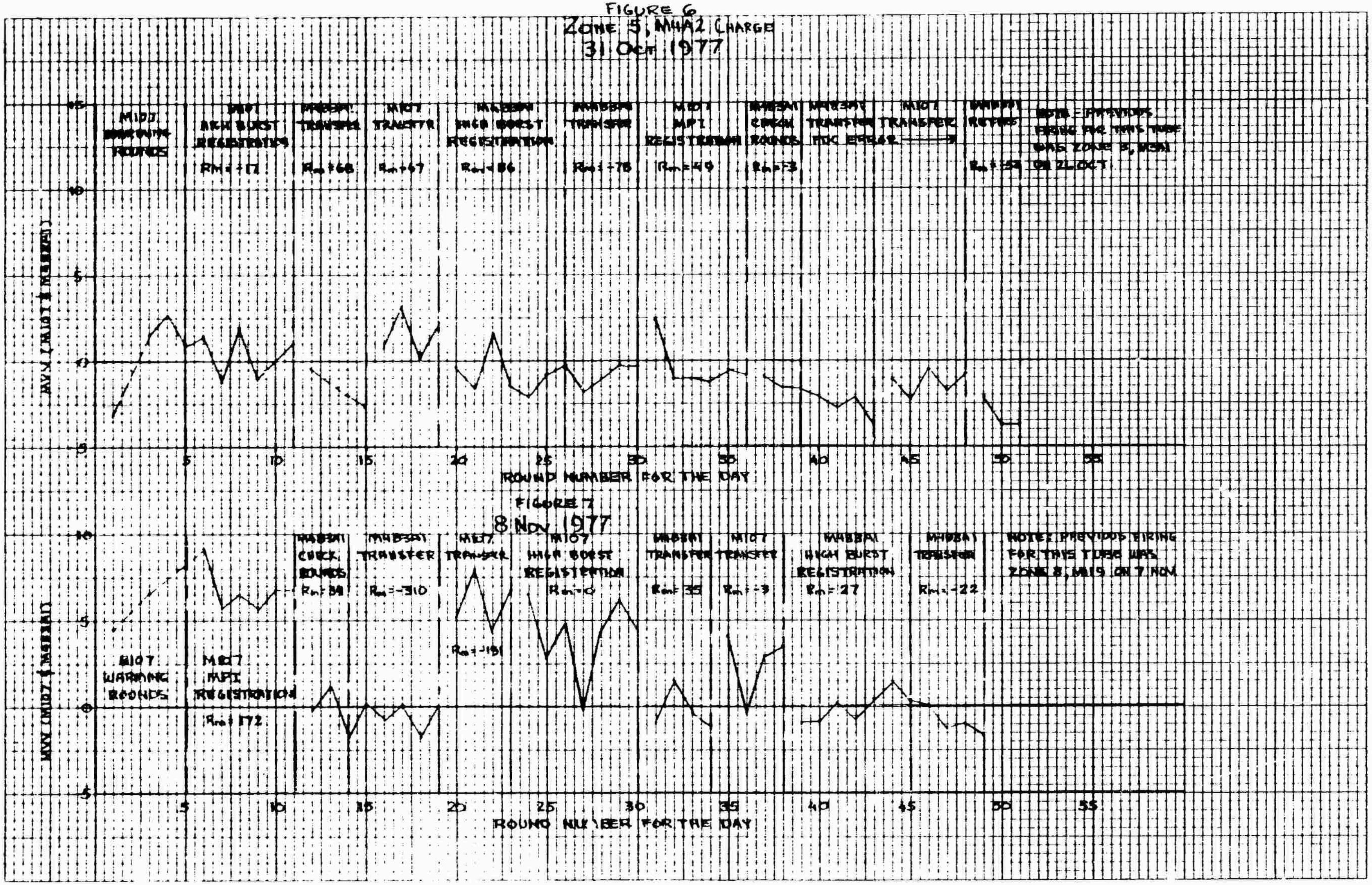


FIGURE 6
ZONE 5, M4A2 CHARGE
31 Oct 1977

FIGURE 7
8 Nov 1977

FIGURE 8

ZONE 7, M4A2 CHARGE

1 NOV 1977

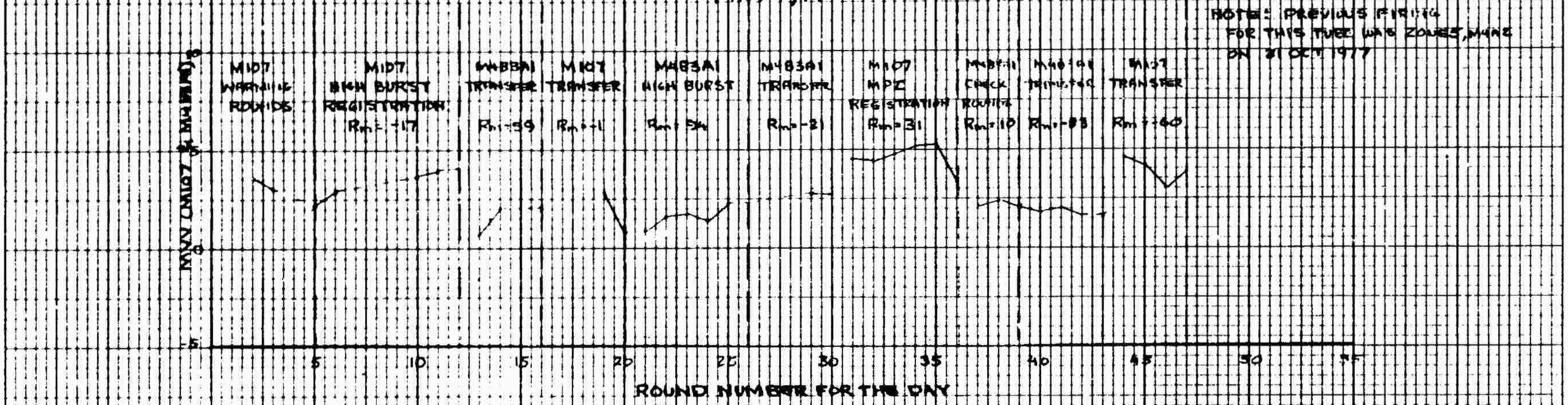


FIGURE 9

9 NOV 1977

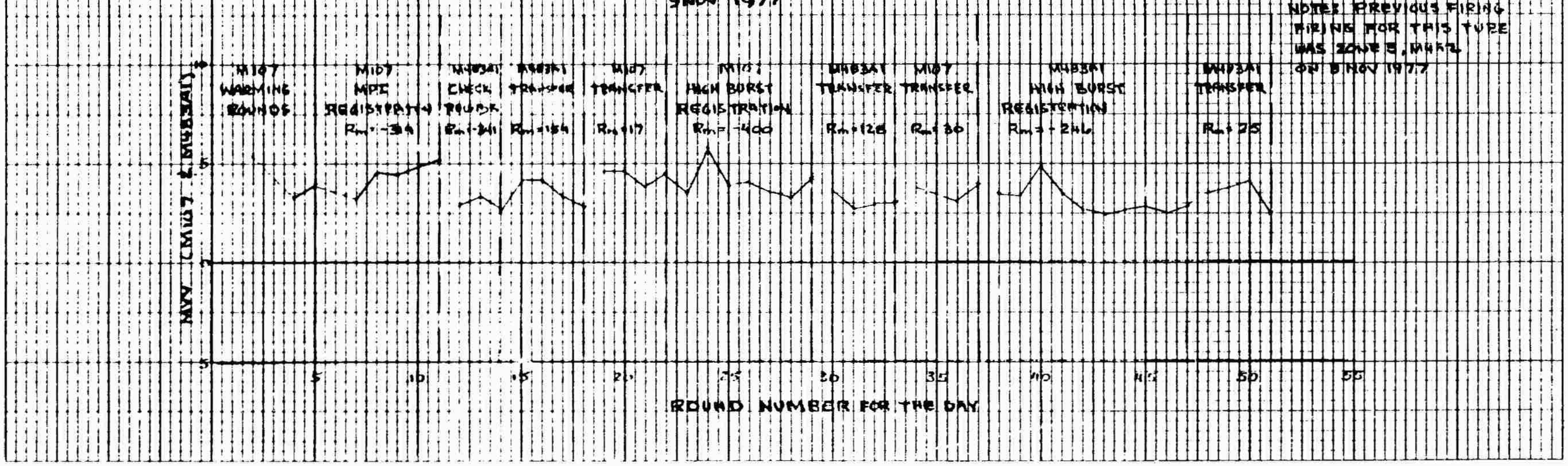
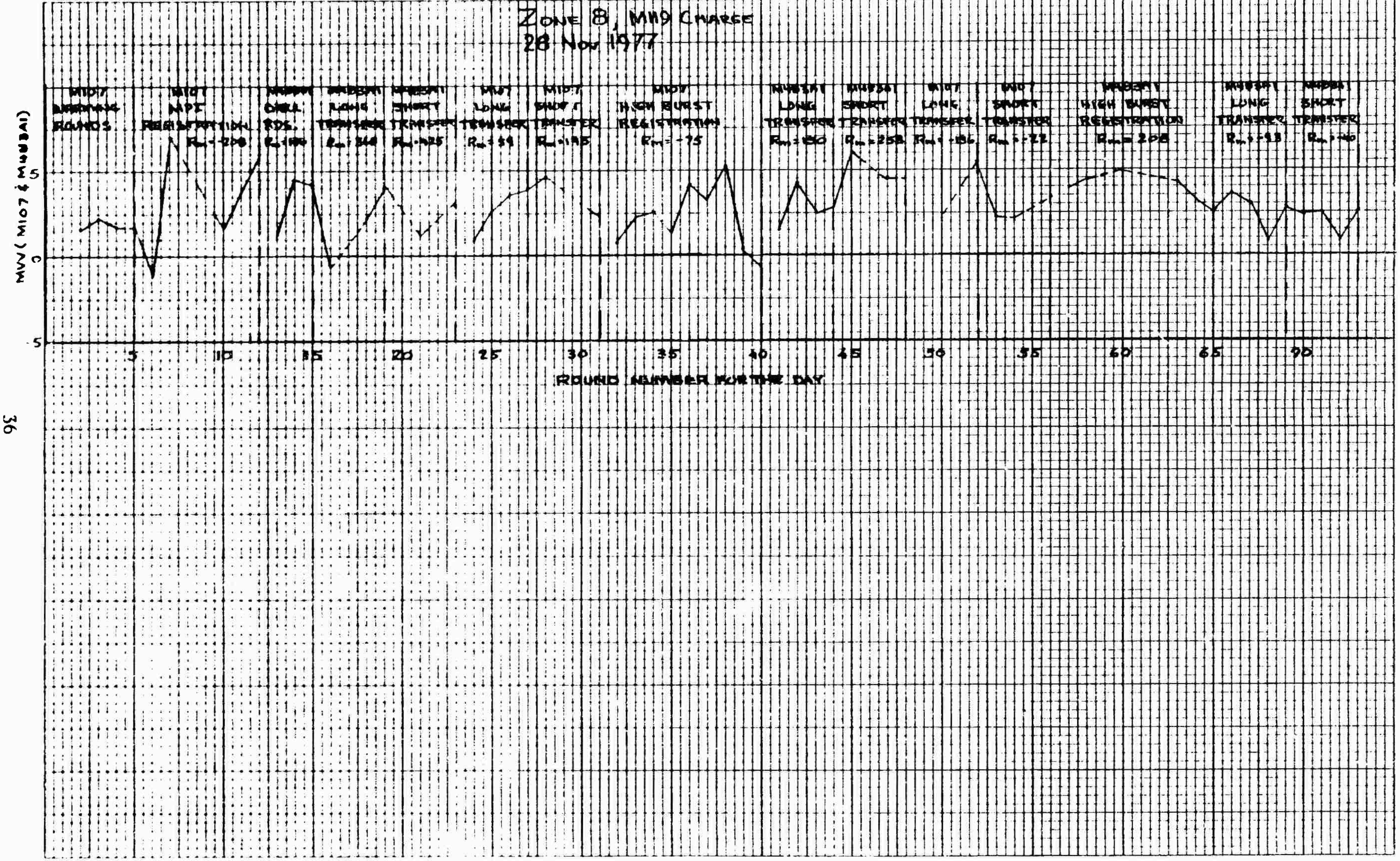


FIGURE 10


Zone 8, M119 Charge
28 Nov 1977
M107
HIGH BURST
REGISTRATION
LONG
SHORT
TRANSFER
HIGH BURST
REGISTRATION
5
0
-5
5
10
15
20
25
30
35
40
45
50
55
60
65
70
ROUND NUMBER FOR THE DAY
MVV (M107 & M483A1)

6.7 Zone 8/M119 Charge.

a. Prior to the start of the test program, the BRL Firing Tables Branch provided an estimate of 5.5 meters per second as the M107 velocity correction for this charge due to the grooved tube. At that time it was stated that this correction was based on very limited data and could be in error. It was agreed that the velocity data from the first replication would be provided to verify and upgrade the correction. However, due to circumstances, it was not possible to fulfill this agreement and complete the test as scheduled. It was, therefore, felt that completing the test was more important. From the velocity data, the grooved tube velocity correction was found to be -10.8 m/s. Due primarily to the magnitude of this correction, many of the transfers had a large miss distance which created a problem in observing the impacts and evaluating all of the data. The data from one occasion were analyzed with the appropriate corrections and are presented in Table 12.

b. In making a comparison of the miss distances in Table 12, the following observations can be made.

1) For the MET+VE technique, the corrected M483A1 average miss distance (two transfers) of 123 meters is comparable to the M107 average miss distance of 127 meters.

2) For the addendum technique, the corrected M483A1 average miss distance of minus 42 meters is slightly better than the M107 miss distance of minus 88 meters.

3) The M483A1 average miss of 123 meters with the MET+VE method is slightly worse than the M483A1 self registration technique average miss distance of minus 57 meters; however, the M483A1 average miss of minus 42 meters with the addendum method is approximately the same as the self registration method.

4) Therefore, in cognizance of the discussion in paragraph 6.4 (comparison of techniques), the Zone 8 M119 charge results appear to follow the same trends. That is, the MET+VE method is the least accurate whereas there is no difference between the self registration and addendum method. Also, for the MET+VE and addendum methods, the M483A1 is just as accurate as the M107 when both rounds are transferred from the same M107 registration.

c. Although the above observations are based on one day's firing (one occasion), it is felt that the results offer sufficient evidence to show that the transfer methods under investigation are as valid for the Zone 8 M119 charge as they are for the other charges previously discussed.

Table 12

Zone 8, M119 Charge
28 Nov 1977

Results Observed and Corrected for Grooved Tube Velocity

Range To Target (M)	Type Proj	Transfer Method	Miss Distances Range (M) Uncorr.	Corr.	Defl. (M)
15000	M483	MET&VE	368	95	44
		Addendum	150	- 96	- 7
		Self Reg	- 93		- 18
	M107	MET&VE	59		8
		Addendum	-136		- 36
12430	M483	MET&VE	425	152	- 4
		Addendum	258	12	- 6
		Self Reg	- 22		- 57
	M107	MET&VE	195		- 35
		Addendum	- 40		- 34

APPENDIX A

Accountable Factors which Influenced the Test Results

1. Test Bias. The test plan required the MET+VE and Addendum transfer methods to be alternated as the first event of the day. The self registration transfer method always followed the addendum method. As discussed in paragraph 6.6, there were occasions where the velocity did not stabilize until after 25 to 30 rounds were fired. As a result, the velocity level of the transfer mission was different than that in the registration causing the transfer to miss the target by 100 meters or more on several occasions. Since the self registration method followed the addendum method, it was always fired from a conditioned tube (with one exception due to weapon failure). Therefore, a comparison of the self registration results to the other methods when fired from an unconditioned tube is not quite valid.

2. Observer Error. Ballistic tests at proving grounds are supported by special instrumentation, computers, personnel with years of experience, and checks and double checks against making human errors. Even with this support, mistakes still occur. Field testing does not have these benefits and controls; nor should they have them. Human error in the field is part of the system and should not be completely stripped out of the test sequence. However, the analyst must be aware of the possible errors that can occur and be able to identify them to make the proper adjustments.

In this test, the rounds within a mission (registration or transfer) were all fired with the same elevation, deflection, and fuze time settings. Therefore, it would be expected that the probable error in range and deflection (corrected for velocity variation) approximate firing table values. There were instances, however, where one round within a group was observed to have a range and/or deflection that was significantly different than the other rounds in the group - sometimes on the order of 200-300 meters in range and over 100 meters in deflection. There are times when one round in a group may be a maverick, but differences of this order of magnitude are very rare. Thus, for the most part, observations such as these must be considered due to human error. In that the primary concern of this test is MPI measurements and not individual round performance, rounds observed to be significantly different than the remaining rounds in the group were discarded and the MPI recomputed. Table 1A provides an example of one such error. The round in question is indicated by an arrow.

Since there are no known reasons for errors of this type, the error has been termed "observer error" for the purposes of this report. It should be noted that out of over 700 rounds included in this analysis, only 10 were discarded due to "observer error."

Table IA

Round by Round Data
Zone 5, M3A1 Charge (M107 w/M582 Fuze)

21 Nov 1977

Event	QE(M)	AZ(M)	Fuze Set(Sec)	Target Miss (M) R	D	HOB	Time Fired
5	426	3314	25.3	217	- 35	-38	1055
M483A1				---	LOST	---	1057
Short				181	- 17	-48	1058
Transfer				156	- 23	-49	1059
6	516	3321	31.4	230	0	-45	1103
M107				236	11	-75	1106
Long				171	- 8	1	1108
Transfer				168	- 9	-11	1109
7	390	3317	23.5	158	- 39	-86	1113
M107				77	- 12	-79	1114
Short				264	-120	-94	1116
Transfer				81	- 21	-90	1117

3. Grooved Tube Velocity Bias

The M185 cannon for the M109A1 howitzer has grooves cut into the forcing cone to prevent projectile fall back. This fix caused a M107 velocity difference from the "ungrooved" version of the M185 cannon. The most current M107 firing table (FT 155-AM-1) was published in September 1972 which was prior to the fix. Since the M109A1 howitzers used in this test were the "grooved" tube version, velocity corrections needed to be made to the M107 registrations for application to the M483A1. The effect on velocity due to the grooving was provided by the Firing Tables Branch of BRL and are as follows:

Charge	Velocity Correction (Meters/Seconds)
Zone 3/M3A1	0.6
Zone 5/M3A1	0.3
Zone 5/M4A2	4.9
Zone 7/M4A2	4.0
Zone 8/M119	-10.8

Except for the Zone 8/M119 charge, these corrections were built into the addendum used to transfer the M483A1 from M107 high burst registrations. The effect of the grooving at Zone 8/M119 was actually unknown prior to the test (estimates were made based on very little data). The correction provided above was based on the firings conducted in this test. For the MET+VE method, the computed M107 VE needed to be adjusted for the velocity bias before application to the M483A1.

A new M107 firing table is now being prepared which will include corrections for the "grooved" tube velocity bias.

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APPENDIX B

Fire Direction Procedures

All firing data for the test were computed using manual fire direction procedures. Fire direction equipment used included firing charts with associated equipment, tabular firing tables (TFT), graphical firing tables (GFT), and graphical site tables (GST) for both the HE M107 and the DP ICM M483A1 projectiles. A firing table addendum providing ballistic corrections from the M107 projectile to the M483A1 projectile was also used. The Field Artillery Digital Automatic Computer (FADAC) was utilized to determine the mean-point-of-impact of all missions fired. The Wang 2200 VP computer was utilized for verification of FADAC determined data.

The following sample missions with Charge 7, M4A2, show a typical day's firing during the test.

MET+VE Technique

The MET+VE Technique involved a mean-point-of-impact (MPI) registration with the M107 HE projectile using the M557 PD (Quick) fuze. Firing data for the registration was derived from standard condition or "cold stick" data (Fig. 1). The chart deflection (3160) was the deflection fired and the elevation (349 mils) was derived corresponding to the chart range (10570). The altitude of the target was 443 meters and the altitude of the howitzer was 398 meters. Site was computed to compensate for the difference in altitude, referred to as the vertical interval (VI). The VI was +45 meters and the computed site was +5 mils. Site was added to the elevation to determine the quadrant to fire (354 mils).

Once the registration was completed, the mean-point-of-impact was determined by FADAC and the actual grid was plotted on the firing chart. The new chart range (10620) and chart deflection (3155) was determined and the GFT setting (corrections for nonstandard conditions) was determined (Fig. 2). The true site (+6 mils) was computed based on the altitude of the MPI (455) and the new MPI chart range. The site was then subtracted from the quadrant fired to determine the adjusted elevation (348 mils). The new chart deflection was compared to the deflection fired to determine the total deflection correction (L5 mils). Drift (L12 mils) was stripped out to determine the GFT Deflection correction (R7 mils). The HE GFT setting was determined to be:

GFT #3, Charge 7, Lot XW, Range 10620, Elevation 348

GFT DF CORR R7

FIGURE 1

M107 MPI Reg

RECORD OF FIRE

CALL FOR FIRE

Observer ________ AF/FFE/IS/S ________ Tgt ________

Grid: ________

Polar: Dir ________ Dis ________ U/D ________ VA ± ________

Shift ________ : Dir ________ L/R ________ +/- ________ U/D ________

TGT 443
BTRY 398
VI +45

∠Si÷10 | 10m Si

Δ FS	
100/R	
/R	
20/R	
HOB Corr	
Si	+5
El	349
QE	354

FIRE ORDER MPI Reg at 27347 36536 <# HE LOT XW FZ Q AMC

Df Corr

INITIAL FIRE COMMANDS | FM | MF # 3 (1) | Rg 10570 | Cht Df 3160

Sp Instr AMC | Sh HE | Lot XW | Chg 7 | Fz Q | Ti | Df 3160

MTO | ∠T | PE_R | TF 31 | in Eff | Ammo Exp (1)

SUBSEQUENT FIRE COMMANDS

Tgt / Dir, MF Sh, Fz	Location / Dev	Priority / Rg	Firing Unit / HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	AMMO Exp	AMMO Type
														354	2	
														354	3	
														354	4	
														354	5	
														354	6	

Btry	DTG	Tgt	Replot Grid	Replot Alt

DA FORM 1 MAY 76 4504 Replaces DA Form 3622, 1 Jan 74 and DA Form 4007, 1 Jan 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

FIGURE 2

HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

For use of this form, see FM 6-40: the proponent agency is US Army Training and Doctrine Command.

COMPUTATION OF HB (MPI) LOCATION

Message to Observers	Dis O1 → O2	Az O1 → O2	
		±	3200
		Az O2 → O1	

Data Fired	Chg 7	Df 3160	FS	QE 354

Observer Readings				Interior Angles			
Rd No	O1 Az	VA	O2 Az	O1 on Left		O1 on Right	
1				Az O1 → HB (MPI)		Az O2 → HB (MPI)	
2				+6400 if necessary		+6400 if necessary	
3				Total		Total	
4				−Az O2 → HB (MPI)		−Az O1 → HB (MPI)	
5				APEX ∢		APEX ∢	
6				Az O2 → HB (MPI)		Az O2 → O1	
7				+6400 if necessary		+6400 if necessary	
8				Total		Total	
9				−Az O2 → O1		−Az O2 → HB (MPI)	
10				∢ at O2		∢ at O2	
				Total			
				Average			

Distance O1 HB (MPI)			
Log base O1 → O2			
+Log sin ∢ at O2			
Sum			
−Log sin Apex Angle			
diff = Log dist O1 HB (MPI)			
Dist O1 → HB (MPI)			

Bearing = 6400 − Az; dE −; dN + (IV) | Bearing = Az; dE +; dN + (I)

dE −; dN −; Bearing = Az − 3200 (III) | dE +; dN −; Bearing = 3200 − Az (II)

Az O1 → HB (MPI) → Bearing
Bearing

Log of dE, dN, and dH

Log dist O1 → HB (MPI)		Log dist O1 → HB (MPI)		Log dist O1 → HB (MPI)	
Log sin Bearing		Log cos Bearing		Log Tan Vert ∢	
Sum = Log dE		Sum = Log dN		Sum = Log dH	

Coordinates of O1	E		N		H	
	± dE		± dN		± dH	
Location of HB (MPI)	E	27 327	N	36 597	H	455

COMPUTATION OF GFT SETTING

Alt HB (MPI)	455	QE fired	354	Chart data to HB (MPI) location Deflection 3155 m Range 10620 M GFT " " Charge 7 Lot XY Range 10620 Elevation 348 Time ____	Df corr L5
−Alt Btry	398	− Site VI/HB (MPI) Rg	+6		L12
VI	⊕ 57	Adj Elev	348		R7

TOTAL
DRIFT
GFT

DA FORM 1 JAN 74 4201 — REPLACES DA FORM 6-55, 1 NOV 67, WHICH IS OBSOLETE.

After the HE GFT setting was determined, a concurrent met (Fig. 3) was worked to determine how much of the total corrections (total deflection correction and total range correction) was due to met (weather) effects and to isolate the remainder of the total effects or the position constants. The M107 tabular firing table was used to solve the met. The met deflection correction was determined to be L6 mils. The position deflection correction (R1 mils) was isolated by subtracting the met correction from the total correction (L5 - L6 = R1).

The total range correction from the HE registration was -80 meters. This total range correction was determined by comparing the registration chart range (10620) to the range corresponding to the adjusted elevation (10540). Solving the concurrent met produced a met range correction of -20 meters, therefore, isolating a ΔV range correction of -60 meters (-80 - (-20) = -60). The ΔV range correction (-60) was divided by the muzzle velocity unit correction factor (-21.5 meters/second) to determine the position ΔV of +2.8 meters/second. The ΔV was reduced by the change to muzzle velocity for nonstandard powder temperature (-4.1 meters/second) to isolate the position VE of +6.9 meters/second (+2.8 - (-4.1) = +6.9.

The position deflection correction, R1, and the position VE, +6.9 m/s, were retained and carried forward into a subsequent met solution (Fig 4) to determine a GFT setting for the M483A1 projectile. The M483A1 tabular firing table was used to solve the subsequent met. In solving a subsequent met, met corrections are determined and added to position corrections to compute new total corrections. The M483A1 met deflection correction was L8, and added to the position correction of R1, produced a total deflection correction of L7. The position, VE, +6.9 m/s corrected for nonstandard powder temperature produced a ΔV of +3.6 m/s and a ΔV range correction of -81 meters. Adding the ΔV range correction to the M483A1 met range correction, -55 meters, the total range correction was determined to be -136 meters (expressed to -140 meters). The total range correction was added to the chart registration range (10620 meters) to determine the range corresponding to the adjusted elevation. (10620 + (-140) = 10480). The adjusted elevation was 356.

From the subsequent met the M483A1 GFT setting was GFT #3, Charge 7, Lot ZW, Range 10620, Elevation 356.

GFT DF CORR R1.

The GFT deflection correction was determined by stripping drift at the adjusted elevation out of the total deflection correction (L7 - L8 = R1).

Immediately after firing the M107 MPI registration, a three round M483A1 MPI check round registration was fired for comparative analysis of total missed distances between the two MPI's. The M483A1 firing data were computed "cold stick" from the M483A1 GFT/GST (Fig. 5). The procedures are the same as noted for the M107 MPI.

FIGURE 3

CONCURRENT MET M107

MET DATA CORRECTION SHEET

For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY DATA				MET MESSAGE				
CHARGE 7	ADJ QE 354	CHART RG 10620	LATITUDE 30°N	TYPE MESSAGE MET B3		OCTANT 1	AREA/UNIT 347983	
ALT OF BTRY (25 m)		400		DATE 01	TIME 1400		ALT MDP 400	PRESSURE 94.3
ALT OF MDP		400		LINE NO. 03	WIND DIR 5800	WIND SPEED 21	AIR TEMP 101.1	AIR DENSITY 93.8
BTRY ABOVE/BELOW MDP (AH)		—		Δ h CORRECTION			± —	± —
ALT OF TARGET (nearest meter)		455		CORRECTED VALUES			101.1	93.8
HEIGHT OF BURST ABOVE TARGET		—						
ALT OF BURST		455						
ALT OF BTRY (nearest meter)		398						
HEIGHT OF TARGET (burst) ABOVE GUN (M)		+57 ≈ +100		COMP RG +15		CHART RG 10620	ENTRY RG 10635	10600

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	TOT DF CORR L5
DIRECTION OF WIND	5800	MET DF CORR L6
		POS DF CORR R1
DIRECTION OF FIRE (4995)	5000	ROTATION CORR L R 1.1
CHART DIRECTION OF WIND	800	DRIFT CORR L 12.5

CROSS WIND: WIND SPEED 21 × COMP R .71 = R 15 KNOTS × .54 UNIT CORR = CROSS WIND CORR R 8.1

RANGE WIND: WIND SPEED 21 × COMP H .71 = TAIL/HEAD 15 KNOTS — MET DEFL CORR L R 5.5 L6

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	T H 15	0	T H 15	+12.0	180.0	
AIR TEMP	101.1	100%	D I 1.1	-10.4		11.4
AIR DENSITY	93.8	100%	D I 6.2	-38.4		238.1
PROJ WEIGHT	4 □	4 □	D I			
ROTATION	+57 × .87				49.6	
					229.6	249.5
						229.6
				MET RANGE CORR		19.9

.20

COMPUTATION OF VE

PROP TEMP 40 °F	VE	+6.9 m/s	+21.8	TOTAL RANGE CORRECTION	-80
	CHANGE TO MV FOR PROP TEMP	-4.1 m/s	-21.5	MET RANGE CORRECTION	-20
	MV	+2.8 m/s	MV UNIT CORRECTION -21.5	VE RANGE CORRECTION	-60
				TOTAL RANGE CORRECTION	

OLD VE ______ + NEW VE ______ = ______ ÷ 2 = AVG VE ______ m/s

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS	
ΔV	D I				.80 / 10540
RANGE WIND	T H				/ 10620 348
AIR TEMP	D I				
AIR DENSITY	D I				
PROJ WEIGHT	D I				TOTAL FUZE CORRECTION
					MET FUZE CORRECTION
					FUZE CORRECTION
		MET FUZE CORR			TOTAL FUZE CORRECTION

OLD FZ CORR ______ + NEW FZ CORR ______ = ______ ÷ 2 = AVG FZ CORR ______

TARGET NO	BATTERY	DATE/TIME

DA FORM 4200, 1 JAN 75 — REPLACES DA FORM 6-15, 1 APR 67, WHICH IS OBSOLETE

U.S. GPO: 1974-…

FIGURE 4

SUPPLEMENT MET M483A1

MET DATA CORRECTION SHEET

For use of this form, see FM 6-40; proponent agency is TRADOC.

BATTERY DATA		MET MESSAGE	
CHARGE: 7	CHART NO: 10620; LATITUDE: 30°N	TYPE MESSAGE: MET B3; OCTANT: 1	AREA/UNIT: 347 983
ALT OF BTRY (10 m)	400	DATE: 01; TIME: 1400; ALT MDP: 400	PRESSURE: 94.3
ALT OF MDP	400	LINE NO: 04; WIND DIR: 5200; WIND SPEED: 15; AIR TEMP: 102.0	AIR DENSITY: 93.2
BTRY ABOVE/BELOW MDP (10 m)	—	Δ h CORRECTION: ± —	± —
ALT OF TARGET (nearest meter)	455	CORRECTED VALUES: 102.0	93.2
HEIGHT OF BURST ABOVE TARGET	—		
ALT OF BURST	455		
ALT OF BTRY (nearest meter)	398		
HEIGHT OF TARGET (burst) ABOVE GUN (10)	+57 ~ +100	COMP NO; CHART NO	ENTRY NO

WIND COMPONENTS AND DEFLECTION

WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD	6400	POS DF CORR R1
DIRECTION OF WIND	5200	MET DF CORR L8
		TOT DF CORR L7
DIRECTION OF FIRE (4995)	5000	DFT DF CORR L8; ROTATION CORR R 1.1
CHART DIRECTION OF WIND	200	GFT DF CORR R1; DRIFT CORR L 8.4

CROSS WIND: WIND SPEED 15 × COMP (L) .20 = (L) 3 KNOTS × .53 UNIT CORR = CROSS WIND CORR (L) 1.6

RANGE WIND: WIND SPEED 15 × COMP (H) .98 = TAIL/HEAD 15 KNOTS; MET DEFL CORR (L) 7.9 — L8

MET RANGE CORRECTION

	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS
RANGE WIND	(T) 15	0	(T) 15	+12.0	180.0	
AIR TEMP	102.0	100%	(I) 2.0	-9.1		18.2
AIR DENSITY	93.2	100%	(D) 6.8	-38.7		263.2
PROJ WEIGHT	5□	4□	(I) 1□	+14.0	14.0	
ROTATION	+37	K .87			32.2	
					226.2	281.4
						226.2
				MET RANGE CORR		55.2 — -55

COMPUTATION OF VE

PROP TEMP 40 °F	VE	+6.9 m/s	+23.0	TOTAL RANGE CORRECTION	
	CHANGE TO MV FOR PROP TEMP	-3.3 m/s	-22.6	MET RANGE CORRECTION	-55
	MV	+3.6 m/s	MV UNIT CORRECTION -22.6	ΔV RANGE CORRECTION	-81
				TOTAL RANGE CORRECTION	-136 — -140

OLD VE ______ + NEW VE ______ ÷ 2 = AVG VE ______ m/s

MET FUZE CORRECTION

	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS
ΔV				
RANGE WIND				
AIR TEMP				
AIR DENSITY				
PROJ WEIGHT				

10480
-140 — 1
10620 356

MET FUZE CORR	TOTAL FUZE CORRECTION
	MET FUZE CORRECTION
	FUZE CORRECTION
	TOTAL FUZE CORRECTION

OLD FZ CORR ______ + NEW FZ CORR ______ ÷ 2 = AVG FZ CORR ______

TARGET NO | BATTERY | DATE/TIME

DA FORM 4200, 1 JAN 74 — REPLACES DA FORM 6-12, 1 APR 67, WHICH IS OBSOLETE

* U.S. GPO: 1974—660-041/6331

M483A1 CK RDS (MPI)

RECORD OF FIRE

CALL FOR FIRE

Observer ______ AF/FFE/IS/S ______ Tgt ______

Grid: ______

Polar: Dir ______ Dis ______ U/D ______ VA± ______

Shift ______ : Dir ______ L/R ______ +/– ______ U/D ______

TGT 443
BTRY 398
VI +45

∢Si÷10 | 10m Si

ΔFS	
100/R	
/R	
20/R	
HOB Corr	
Si	+5
El	363
QE	368

FIRE ORDER MPI REG AT 27347 36536, SH ICM, LOT ZW, FZ Q (D98.0) MC

Df Corr

INITIAL FIRE COMMANDS | FM | MF #3 (1)

Rg 10680 | Cht Df 3160

Sp Instr AMC | Sh ICM | Lot ZW | Chg 7 | Fz Q | Ti D98.0 | Df 3160

MTO | ∢T | PE_R | TF 32 | in Eff | Ammo Exp (1)

Tgt	Location	Priority ✓	Firing Unit	SUBSEQUENT FIRE COMMANDS											AMMO	
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
														368	(2)	
														368	(3)	

Btry | DTG | Tgt | Replot Grid | Replot Alt

DA FORM 4504, 1 MAY 76. Replaces DA Form 3022, 1 Jan 74 and DA Form 4007, 1 Jan 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

FIGURE 5

Once the GFT setting for both the M483A1 and the M107 projectiles were determined, four round MPI transfers were fired with both projectiles at the same target.

The M483A1 transfer firing data were determined using the M483A1 GFT with the GFT setting determined from the subsequent met (Fig 6). The deflection to fire (3234 mils) was computed by determining the mission deflection correction, L6 (GFT DF CORR R1 + Drift DF CORR L7) and applying it to the chart deflection (3228 mils). Site (+28 mils) was computed as previously discussed (note the 200 height of burst) and added to the elevation of 292 mils to determine the quadrant to fire (320 mils). To determine the fuze setting to fire, comp site had to be computed. When the VI exceeds 100 meters, the fuze setting must correspond to elevation plus comp site. To determine comp site, determine both site (+28 mils) and angle of site (+26 mils) from the GST. Subtract the angle of site from site and the remainder is comp site (+2 mils) elevation plus comp site (294 mils).

The M107 Transfer was fired at the same target. The procedures for determining M107 firing data are the same as those for determining M483A1 data, except that the M107 GFT/GST is used with the M107 GFT setting from the M107 MPI registration (Fig. 7).

FIGURE 6

M483A1 SHORT TRANSFER

RECORD OF FIRE

CALL FOR FIRE

Observer ________ AF/FFE/IS/S ________ Tgt ________

Grid: ________

Polar: Dir ________ Dis ________ U/D ________ VA ± ________

Shift ________ : Dir ________ L/R ________ +/- ________ U/D ________

TGT 440
HOB +200
+640
BTRY 398
VI +242

GFT R1
DFT L7

∢Si÷10 | 10 m Si

△ FS	
100/R	
/R	
20/R	
HOB Corr	
Si	+28
El	292
QE	320

FIRE ORDER

Df Corr L6

INITIAL FIRE COMMANDS FM MF # 3(4) Rg 9430 Cht Df 3228

Sp Instr BY RD AMC Sh ICM Lot ZW Chg 7 Fz TI Ti 26.5 Df 3234

MTO ∢T PE$_R$ TF in Eff Ammo Exp (4)

Tgt: Dir, MF Sh, Fz	Location: Dev	Priority: Rg	Firing Unit: HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	AMMO Exp	AMMO Type
SI =	+28			EL =	292		FS ~	294	= 26.5							
ΔSI =	+26			CAS	+2											
CAS	+2			EL+CAS	294											

Btry	DTG	Tgt	Replot Grid	Replot Alt

DA FORM 4504, 1 MAY 76

Replaces DA Form 3022, 1 Jan 74 and DA Form 4007, 1 Jun 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

FIGURE 7

M107 SHORT TRANSFER

RECORD OF FIRE

CALL FOR FIRE

Observer ________ AF/FFE/IS/S ________ Tgt ________

Grid: ________

Polar: Dir ________ Dis ________ U/D ________ VA ± ________

Shift ________ : Dir ________ L/R ________ +/- ________ U/D ________

TGT	440
HOB	+200
	1640
BTRY	398
VI	+242

GFT R7
DFT L10

+ Si ÷ 10 | 10 mil Si

Δ FS
100/R
/R
20/R
HOB Corr

FIRE ORDER

Df Corr	L3
Si	+28
Cht Df	3228
El	285
Df	3231
QE	313

INITIAL FIRE COMMANDS | FM | MF # 3 (4) | Rg 9430

Sp Instr BY RD AMC | Sh HE | Lot XW | Chg 7 | Fz TI | Ti 26.3

MTO | ± T | PE R | TF | in Eff | Ammo Exp (4)

Tgt	Location	Priority	Firing Unit	SUBSEQUENT FIRE COMMANDS											AMMO	
Dir, MF Sh, Fz	Dev	Rg	HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	Exp	Type
31 =	+28			EL =	285		FS ~	287	= 26.3							
451 =	+26			CAS =	+2											
C/S =	+2			EL+CAS =	287											

Btry | DTG | Tgt | Replot Grid | Replot Alt

DA FORM 4504, 1 MAY 76 — Replaces DA Form 3022, 1 Jan 74 and DA Form 4007, 1 Jan 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

Firing Table Addendum Technique

The firing table addendum technique involved a high burst (HB) registration using the M107 HE projectile with either the M564 or M582 mechanical time fuze. Once again firing data for the registration was derived from "cold stick" data (Fig. 8). The chart deflection was 3160 mils and the elevation corresponding to chart range was 349 mils. Since this registration was a high burst, a height of burst of 100 meters was fired, therefore, the VI was +145 meters and site was +15 mils. The quadrant elevation was 364 mils. The fuze setting fired was determined corresponding to elevation plus comp site (VI greater than 100 meters). Site was +15 mils, angle of site was +14 mils, therefore, comp site was +1 mils. The fuze setting corresponding to elevation plus comp site of 350 mils was 31.0 seconds. Again, six useable rounds were fired to determine the HB location.

Once the actual location of the HB was determined, the GFT setting (Fig. 9) was computed using the same procedures as discussed in the MPI registration. The only additional computation was the adjusted time. To compute the adjusted time, the time corresponding to the adjusted elevation plus comp site was first determined, 30.5 seconds. This fuze setting was compared to the actual time fired, 31.0 seconds, to determine the total fuze correction, +0.5 seconds. The total fuze correction was then applied to the time corresponding to the adjusted elevation, 30.4 seconds, to determine the adjusted time, 30.9 seconds (30.4 + 0.5 = 30.9).

The GFT setting was: GFT #3, Charge 7, Lot XW, Range 10570, Elevation 342, Time 30.9.

GFT DF CORR L1.

A four round transfer mission was then fired with the M483A1 projectile based on the M107 HB registration corrections (Fig. 10)and the firing table addendum ballistic corrections (Fig. 11). The firing data for the M107 projectile were first computed as previously discussed in the first M107 transfer. The only exception was a weight correction for the M483A1 since the M107 data had to be corrected for the M483A1 projectile. The M483A1 projectile weighed 5 square and the M107 weighed 4 square. Therefore, a range correction of +17 meters for a 1 square weight difference was applied to the chart range, expressing it to 9450 meters (9430 + 17 = 9447 ∿ 9450). Once the M107 data were determined, Ti 26.6 seconds, DF 3239 mils, QE 311 mils, the ballistic corrections for the M483A1 were extracted from the addendum. Entering the addendum with QE 310 mils (nearest listed value) and HOB above gun of 242 meters, the corrections were QE +10 mils, FS + 0.3 seconds, DF R3 mils. Applying the corrections, the M483A1 data are Ti 26.9, DF 3236, QE 321.

The M107 transfer using corrections from the HB registration was then fired (Fig. 12). Procedures followed were as already discussed.

FIGURE 8

M107 HE REG

RECORD OF FIRE

CALL FOR FIRE

Observer ______ AF/FFE/IS/S ______ Tgt ______

Grid: ______

Polar: Dir ______ Dis ______ U/D ______ VA ± ______

Shift ______ : Dir ______ L/R ______ +/- ______ U/D ______

TGT 443
HOB 100
543
BIEY 398
VI +145

+ Si ÷ 10 | 10 m Si

ΔFS	
100/R	12
/R	
20/R	
HOB Corr	
Si	+15
El	349
QE	364
Ammo Exp	(1)

FIRE ORDER HB REG at 27347 36536, HOB +100, SH HE, LOT XW, FZ TI, MC

Df Corr 0

INITIAL FIRE COMMANDS | FM | MF #3 (1)

Rg 10570 | Cht Df 3160

Sp Instr AMC | Sh HE | Lot XW | Chg 7 | Fz TI | Ti 31.0 | Df 3160

MTO | ΔT | PE_R | TF 31 | in Eff

Tgt Dir, MF Sh, Fz	Location Dev	Priority Rg	Firing Unit HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	AMMO Exp	AMMO Type
SI =	+15			EL =	349		FS ~	350 =	31.0					364	(2)	
ΔSI =	+14			CAS =	+1									364	(3)	
CAS =	+1			EL/CAS	350									364	(4)	
														364	(5)	
														364	(6)	
														364	(7)	TI

Btry	DTG	Tgt	Replot Grid	Replot Alt

DA FORM 1 MAY 74 4504 Replaces DA Form 3022, 1 Jan 74 and DA Form 4967, 1 Jan 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

FIGURE 9

HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

For use of this form, see FM 6-40; the proponent agency is US Army Training and Doctrine Command.

COMPUTATION OF HB (MPI) LOCATION

~~Message to Observers~~ SI = +22 +SI = +20 CAS = +2 EL = 342 CAS = +2 EL+CAS = 344 FS ~ 344 = 30.5 EL 342 — 30.4 EL+CAS 344 — 30.5 +0.5 TI FIRE 31.0 +0.5 ADJ TI 30.9	Dis 01 → 02	Az 01 → 02 ± Az 02 → 01	3200

Date Fired	Chg 7	Df 3160	FS 31.0	QE 364

Rd No	01 Az	VA	02 Az	01 on Left		01 on Right	
1				Az 01 → HB (MPI)		Az 02 → HB (MPI)	
2				+6400 if necessary		+6400 if necessary	
3				Total		Total	
4				−Az 02 → HB (MPI)		−Az 01 → HB (MPI)	
5				APEX ∠		APEX ∠	
6				Az 02 → HB (MPI)		Az 02 → 01	
7				+6400 if necessary		+6400 if necessary	
8				Total		Total	
9				−Az 02 → 01		−Az 02 → HB (MPI)	
10				∠ at 02		∠ at 02	
				Total			
				Average			

Distance 01 HB (MPI)		
Log base 01 → 02		
+Log sin ∠ at 02		
Sum		
−Log sin Apex Angle		
diff = Log dist 01 HB (MPI)		
Dist 01 → HB (MPI)		

Bearing = 6400 − Az; dE −; dN +

Bearing = Az; dE +; dN +

IV | I

III | II

dE −; dN −; Bearing = Az − 3200

dE +; dN −; Bearing = 3200 − Az

Az 01 → HB (MPI) = Bearing

Bearing

SI = +22
+SI = +20
CAS = +2

EL = 342
CAS = +2
EL + CAS = 344

TI ~ 344 = 30.

Log of dE, dN, and dH

Log dist 01 → HB (MPI)		Log dist 01 → HB (MPI)		Log dist 01 → HB (MPI)	
Log sin Bearing		Log cos Bearing		Log Tan Vert ∠	
Sum = Log dE		Sum = Log dN		Sum = Log dH	

Coordinates of 01	E		N		H	
	± dE		± dN		± dH	
Location of HB (MPI)	E	27 390	N	36 671	H	610

COMPUTATION OF GFT SETTING

Alt HB (MPI)	610	QE fired	364	Chart data to HB (MPI) location Deflection 3147 at Range 10570 m GFT ___ Charge 7 Lot XW Range 10570 Elevation 342 Time 30.9	Df corr L13
−Alt Btry	398	−Site VI/HB (MPI) Rg	−(+22)		L12
VI	+212	Adj Elev	342		L1

DA FORM 4201, 1 JAN 74 — REPLACES DA FORM 6-88, 1 NOV 67, WHICH IS OBSOLETE.

FIGURE 10

M483A1 SHORT TRANSFER

RECORD OF FIRE

CALL FOR FIRE

Observer ______ AF/FFE/IS/S ______ Tgt ______

Grid: ______

Polar: Dir ______ Dis ______ U/D ______ VA± ______

Shift ______ : Dir ______ L/R ______ +/- ______ U/D ______

TGT 440
HOB +200
+640
BTRY 398
VI +242

GFT 41
DFT 40

+Si÷10 | 10 m Si

ΔFS	
100/R	11
/R	
20/R	
HOB Corr	
Si	+28
El	283/311
QE	321
Ammo Exp	4

FIRE ORDER

Df Corr L11

INITIAL FIRE COMMANDS | FM | MF #3 (4) | Rg 9430 (26.6) | Cht Df 3228/3239

Sp Instr RY RD AMC | Sh ICM | Lot ZW | Chg 7 | Fz Ti | Ti 26.9 | Df 3236

MTO | +T | PE_R | TF | in Eff

Tgt: Dir, MF Sh, Fz	Location: Dev	Priority: Rg	Firing Unit: HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	AMMO: Exp	AMMO: Type
SI =	+28			EL 283					RG		9430					
ΣSI =	+26			CAS +2				ΔRG/1WT D			+17					
CAS =	+2			EL ICM 285					RG		9447	~	9450			
				FS ~ 285 =		26.6										
				HE DATA		26.6			3239					311		
				ADD CORR		+0.3			23					+10		
				ICM DATA		26.9			3236					321		

Btry	DTG	Tgt	Replot Grid	Replot Alt

DA FORM 1 MAY 76 4504 Replaces DA Form 3822, 1 Jan 74 and DA Form 4007, 1 Jan 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

FIGURE 11

CHARGE
7W

BALLISTIC DIFFERENCES

PROJ, HE, M483A1

CORRECTIONS TO COMPENSATE FOR BALLISTIC DIFFERENCES
BETWEEN PROJ, HE, M107 WITH FUZE, MTSQ, M564 AND PROJ, HE, M483A1

QUAD ELEV M107		HEIGHT OF BURST ABOVE GUN - METERS							
MILS		-400	-300	-200	-100	0	100	200	300
300	QE	12.1	11.7	11.3	10.9	10.6	10.2	9.9	9.5
	FS	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
	DO	R3.3	R3.2	R3.2	R3.1	R3.0	R2.9	R2.9	R2.8
305	QE	12.4	12.0	11.6	11.2	10.8	10.5	10.1	9.7
	FS	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
	OD	R3.3	R3.3	R3.2	R3.1	R3.1	R3.0	R2.9	R2.8
310	QE	12.7	12.3	11.9	11.5	11.1	10.7	10.3	10.0
	FS	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3
	OD	R3.3	R3.3	R3.2	R3.2	R3.1	R3.0	R2.9	R2.8
315	QE	13.0	12.6	12.2	11.7	11.3	11.0	10.6	10.2
	FS	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3
	OD	R3.4	R3.3	R3.3	R3.2	R3.1	R3.1	R3.0	R2.9
320	QE	13.3	12.9	12.5	12.0	11.6	11.2	10.8	10.4
	FS	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3
	DD	R3.4	R3.3	R3.3	R3.2	R3.2	R3.1	R3.0	R2.9
325	QE	13.6	13.2	12.8	[illegible]	11.9	11.5	11.1	10.7
	FS	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3
	OD	R3.4	R3.4	R3.3	R3.3	R3.2	R3.1	R3.0	R3.0
330	QE	14.0	13.5	13.1	12.6	12.2	11.8	11.3	10.9
	FS	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
	DD	R3.5	R3.4	R3.3	R3.3	R3.2	R3.2	R3.1	R3.0
335	QE	14.3	13.8	13.4	12.9	12.5	12.1	11.6	11.2
	FS	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	DO	R3.5	R3.4	R3.4	R3.3	R3.3	R3.2	R3.1	R3.0
340	QE	14.6	14.2	13.7	13.3	12.8	12.4	11.9	11.5
	FS	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4
	DO	R3.5	R3.5	R3.4	R3.3	R3.3	R3.2	R3.2	R3.1
345	QE	15.0	14.5	14.0	13.6	13.1	12.7	12.2	11.8
	FS	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4
	OD	R3.5	R3.5	R3.4	R3.4	R3.3	R3.3	R3.2	R3.1

FIGURE 12

M107 SHORT TRANSFER

RECORD OF FIRE

CALL FOR FIRE

Observer ____________ AF/FFE/IS/S ________ Tgt ____________

Grid: ____________

Polar: Dir ________ Dis ________ U/D ________ VA ± ________

Shift ________ : Dir ________ L/R ________ +/- ________ U/D ________

TGT 440
HOB +200
640
BRY 398
VI +242

GFT 41
DFT 410

∢Si÷10 | 10 m Si

Δ FS	
100/R	11
/R	
20/R	
HOB Corr	
Si	+28
El	282
QE	310
Ammo Exp	4

FIRE ORDER

Df Corr L11

Cht Df 3228

INITIAL FIRE COMMANDS FM MF +1 3(4) Rg 9430

Sp Instr BY RD AMC | Sh HE | Lot XW | Chg 7 | Fz TI | Ti 26.5 | Df 3235

MTO | ∢T | PE_R | TF | in Eff

Tgt: Dir, MF Sh, Fz	Location: Dev	Priority: Rg	Firing Unit: HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	AMMO: Exp	AMMO: Type
SI	+28			EL	282											
tSI	+26			CAS	+2											
CAS	+2			EL+CAS	284											
				FS ~ 284 =		26.5										

Btry	DTG	Tgt	Replot Grid	Replot Alt

DA FORM 1 MAY 76 4504 Replaces DA Form 3622, 1 Jan 74 and DA Form 4007, 1 Jan 73, which are obsolete. For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

M483A1 Self Registration Technique.

The self registration technique involved a HB registration (Fig. 13 and 14) and transfers (Fig. 15) with the M483A1 with the M577 mechanical time fuze. All procedures and gunnery techniques were the same as discussed with the M107 registrations and transfers. The M483A1 TFT/GFT/GST were used for computation.

FIGURE 13

M483A1 HB Reg

RECORD OF FIRE

CALL FOR FIRE

Observer ______ AF/FFE/IS/S ______ Tgt ______

Grid: ______

Polar: Dir ______ Dis ______ U/D ______ VA ± ______

Shift ______ : Dir ______ L/R ______ +/- ______ U/D ______

TGT 443
HOB +100
543
BTRY 348
VI +145
∢Si÷10 | 10 m Si

Δ FS	
100/R	
/R	
20/R	
HOB Corr	
Si	+16
El	362
QE	378

FIRE ORDER HB Reg at 27437 36536 HOB +100 SH ICM, LOT 2W, FZ TI, AMC

Df Corr ______

INITIAL FIRE COMMANDS FM ______ MF # 3 (1) Rg 10570 Cht Df 3160

Sp Instr AMC Sh ICM Lot 2W Chg 7 Fz TI Ti 31.6 Df 3160

MTO ______ ∢T ______ PE_R ______ TF ______ in Eff ______ Ammo Exp (1)

Tgt: Dir, MF Sh, Fz	Location: Dev	Priority: Rg	Firing Unit: HOB Corr	MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	AMMO: Exp	AMMO: Type
SI =	+16			EL =	362		FS ~	364	= 31.6					378	(2)	
ΔSI =	+14			CAS =	+2									378	(3)	
CAS =	+2			EL+CAS =	364									378	(4)	
														378	(5)	
														378	(6)	ICM

Btry ______ DTG ______ Tgt ______ Replot Grid ______ Replot Alt ______

DA FORM 4504, 1 MAY 76 — Replaces DA Form 3622, 1 Jan 74 and DA Form 4007, 1 Jan 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

FIGURE 14

HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION

For use of this form, see FM 6-40; the proponent agency is US Army Training and Doctrine Command.

COMPUTATION OF HB (MPI) LOCATION

~~Message to Observers~~

SI = +13
ΔSI = +11
CAS = +2

EL = 365
CAS = +2
EL+CAS = 367

EL 363 | EL+CAS 367 | TI FIRED 31.6
-0.3
31.9
ADJ TI 31.4
0.3
31.7

Dis O1 → O2	Az O1 → O2	
	±	3200
	Az O2 → O1	

Date Fired	Chg 7	Df 3160	FS 31.6	QE 378

Rd No	O1 Az	VA	O2 Az	Interior Angles — O1 on Left		O1 on Right	
1				Az O1 → HB (MPI)		Az O2 → HB (MPI)	
2				+6400 if necessary		+6400 if necessary	
3				Total		Total	
4				−Az O2 → HB (MPI)		−Az O1 → HB (MPI)	
5				APEX ∡		APEX ∡	
6				Az O2 → HB (MPI)		Az O2 → O1	
7				+6400 if necessary		+6400 if necessary	
8				Total		Total	
9				−Az O2 → O1		−Az O2 → HB (MPI)	
10				∡ at O2		∡ at O2	
				Total			
				Average			

Distance O1 HB (MPI)	
Log base O1 → O2	
+Log sin ∡ at O2	
Sum	
−Log sin Apex Angle	
diff = Log dist O1 HB (MPI)	
Dist O1 → HB (MPI)	

Bearing = 6400 − Az; dE −, dN + (IV) | Bearing = Az; dE +, dN + (I)
Bearing = Az − 3200; dE −, dN − (III) | Bearing = 3200 − Az; dE +, dN − (II)

Az O1 → HB (MPI) = Bearing

Bearing

Log of dE, dN, and dH

Log dist O1 → HB (MPI)	Log dist O1 → HB (MPI)	Log dist O1 → HB (MPI)	
Log sin Bearing	Log cos Bearing	Log Tan Vert ∡	
Sum = Log dE	Sum = Log dN	Sum = Log dH	

	E	N	H
Coordinates of O1			
	± dE	± dN	± dH
Location of HB (MPI)	27 269	36 628	516

COMPUTATION OF GFT SETTING

Alt HB (MPI)	516	QE fired	378
−Alt Btry	398	−Site VI/HB (MPI) Rg	−(+13)
VI	+118	Adj Elev	365

Chart data to HB (MPI) location: Deflection 3133 at Range 10680 M
GFT "   " Charge 7 Lot [illegible]
Range 10680 Elevation 365 Time 31.4

Df corr
L7
L8
R1

DA FORM 1 JAN 74 4201 — Replaces DA Form 6-66, 1 NOV 67, which is obsolete.

FIGURE 15

M483A1 SR SHOT TRANSFER

RECORD OF FIRE

CALL FOR FIRE

Observer ______ AF/FFE/IS/S ______ Tgt ______

Grid: ______

Polar: Dir ______ Dis ______ U/D ______ VA± ______

Shift ______ : Dir ______ L/R ______ +/- ______ U/D ______

TGT 440
HC 1080
640
BTRY 398
VI +242

GFT R1
DFT L7

+Si÷10 | 10 mil Si

ΔFS	
100/R	
/R	
20/R	
HOB Corr	

FIRE ORDER

Df Corr L6 | Si +28

INITIAL FIRE COMMANDS | FM | MF #3 (4) | Rg 9430 | Cht Df 3228 | El 296

Sp Instr BY RD AMC | Sh ICM | Lot ZW | Chg 7 | Fz T/ | Ti 26.6 | Df 3234 | QE 324

MTO | ∢T | PE_R | TF | in Eff | Ammo Exp (4)

Tgt Dir, MF Sh, Fz	Location Dev	Priority Rg	Firing Unit HOB Corr	SUBSEQUENT FIRE COMMANDS MF, Sh Chg, Fz	FS Corr	Ti	Chart Df	Df Corr ( )	Df Fired	Chart Rg	HOB Corr	Si ( )	El	QE	AMMO Exp	Type
SI =	+28			EL =	296		FS ~	298 =	26.6							
±SI =	+26			CAS =	+2											
CAS =	+2			EL+CAS =	298											

Btry | DTG | Tgt | Replot Grid | Replot Alt

DA FORM 4504, 1 MAY 76. Replaces DA Form 3022, 1 Jan 74 and DA Form 4007, 1 Jan 73, which are obsolete.

For use of this form, see FM 6-40 and FM 6-40-5; the proponent agency is US Army Training and Doctrine Command.

APPENDIX C

Velocity Trends and Their Effects on Accuracy (Further Discussion)

The phenomena of velocity variation due to tube conditioning, history, wear, etc., have been the subject of many studies over the last thirty years. Beginning with a report published in 1945 by MAJ John M. Swalm, Jefferson Proving Ground, Indiana, and continuing through some recent evaluations in AMSAA's ammunition stockpile reliability program (ASRP), there are many examples and observations made concerning the effects of tube conditioning on velocity. It is interesting to note that many of MAJ Swalm's observations still hold true today. For example, the following are a few excerpts from his report concerning propellant assessment at Army proving grounds.

"It was further observed that the rate of fire had a contributing effect on erratic velocities, and that almost every time the crew and proof director speeded the program up in order to get the last few rounds fired there was a substantial drop in velocity in those last rounds. A constant rate of fire, therefore, was made mandatory; and, coupled with the bag diameter limitation, some improvement was obtained in the velocity uniformity."

"Early in 1944 it was observed that there were lengthy trends in the low zones of the 105mm M2A1 How. It was not believed that such trends would affect the accuracy of the charge assessments, for the test and standard rounds were equally affected; but, where absolute velocity values were of paramount importance, such as in standardization firings, proper conditioning could not be overemphasized. In the dualgran 105 howitzer firings considerable effort was devoted to the evaluation and elimination of trends, which were particularly apparent in the lower zones; it was definitely established that tube temperature, coppering, and other factors affecting bore resistance were the causes of the velocity trends, and it was found that by heating the tube either by steam or by firing full charge rounds, and by decoppering with tin or lead foil, the low zone trends could be drastically reduced but not completely eliminated. In a way, this was duplicated in the regular powder testing of all the single-perforated howitzer charges, i.e., the 105 M3 How., the M3 charge for the 155 How., and the M1 charge for the 8 inch How., where the second and third test of any one day in the same tube was observed to fire at higher velocity levels than the first test of the day; in the first firing, of course, the tube was cold, but for the following firings it was quite warm, even hot. It was observed that the colder the tube, the more conditioning was required, or else the lower the velocity level obtained with the fast powder. The slower multi-perforated powders did not seem to have such definite trends, and responded quite differently to conditioning, being longer in duration but less in magnitude."

"EFFECT OF PRECEDING ROUND CHARGE WEIGHT ON VELOCITY"

"One of the most interesting observations made in 1945 was that in new high-velocity guns of medium caliber the velocity of a given round could be affected by a slightly different charge weight of exactly the same powder lot in the immediately preceding round. In regular powder tests, ISL 166 Rev. 2 Amend 1 allowed test powder velocities to vary from the standard by 1.5 per cent, so that two test lots fired alternately could be 3 per cent part in velocity. It had not been thought that such a practice would cause measurable errors in charge assessment; however, in the investigation of the M28-M40 primer effects on each other, when alternated in the 76mm gun, there was some evidence that the magnitude of the effects depended on the weights of powder charge used. Special tests were therefore fired in a new 76mm tube with different weights of the same powder lot corresponding to 3 per cent velocity difference fired in alternate rounds; it was found that each charge fired about ten ft/sec. lower or higher than normal when the preceding round was the extreme low charge or high charge, respectively. The same observation was then made in a new 90mm tube, although the magnitude was a little less; however, in a moderately worn 90mm tube there appeared to be no effect. If the values observed in the 76mm gun were correct, then a maximum error of about 15 ft/sec. high or low could be made in the charge assessment of a powder lot which fired just within the 1.5 per cent limit of the directive, in a new tube. The reason for this effect is probably varying bore resistan e, through different residual products of ignition or different distribution of the copper deposits in the bore."

"One of the most interesting observations of the effect which bore resistance can have on velocity level was made at Radford Proving Ground in late 1944 in the 105 How. M2A1. After more than 5000 regular rounds in How. No. 59 some special assessments of double base, high-velocity powder were made; before this, a velocity of 1550 ft/sec. was being obtained with the regular standard powder, but, as the special tests continued, higher and higher values were observed in concurrently fired regular powder tests, until a rise of about 30 ft/sec. in the regular standard level had occurred. The special firings were then terminated, and in successive tests the regular standard velocity slowly and evenly dropped back down to its original level, or even a little lower as a result of the erosion which had taken place with the double base powder."

In 1965, the Surveillance and Reliability Lab. of BRL, which was later to become RAM Division of AMSAA, conducted a special test on the 105mm M67 propelling charge. In this test, a difference in velocity level between days was observed when firing Charge 1. On the first day, after Charge VII and Charge V had already been fired, Charge I velocities were consistently at firing table level (see Figure 1). On the second day, which began with Charge I, the level was approximately ten fps lower than the first day. In addition, as further evidence of this effect,

at the end of that day's firing (following Charges V and VII), six additional rounds were fired at Charge I and the velocities for these rounds were at the same level as those obtained for the first day's firing, indicating a definite conditioning factor associated with Charge I (see Figure II).

From these results it was concluded that approximately 25-30 conditioning rounds are required in order to reach and maintain the velocity level given in the firing table for Charge I.

During AMSAA's independent evaluation role during the M198 howitzer development, the RAM Division made some observations on velocity creep and tube memory on velocity variation for the M198 howitzer and its proposed propelling charges.

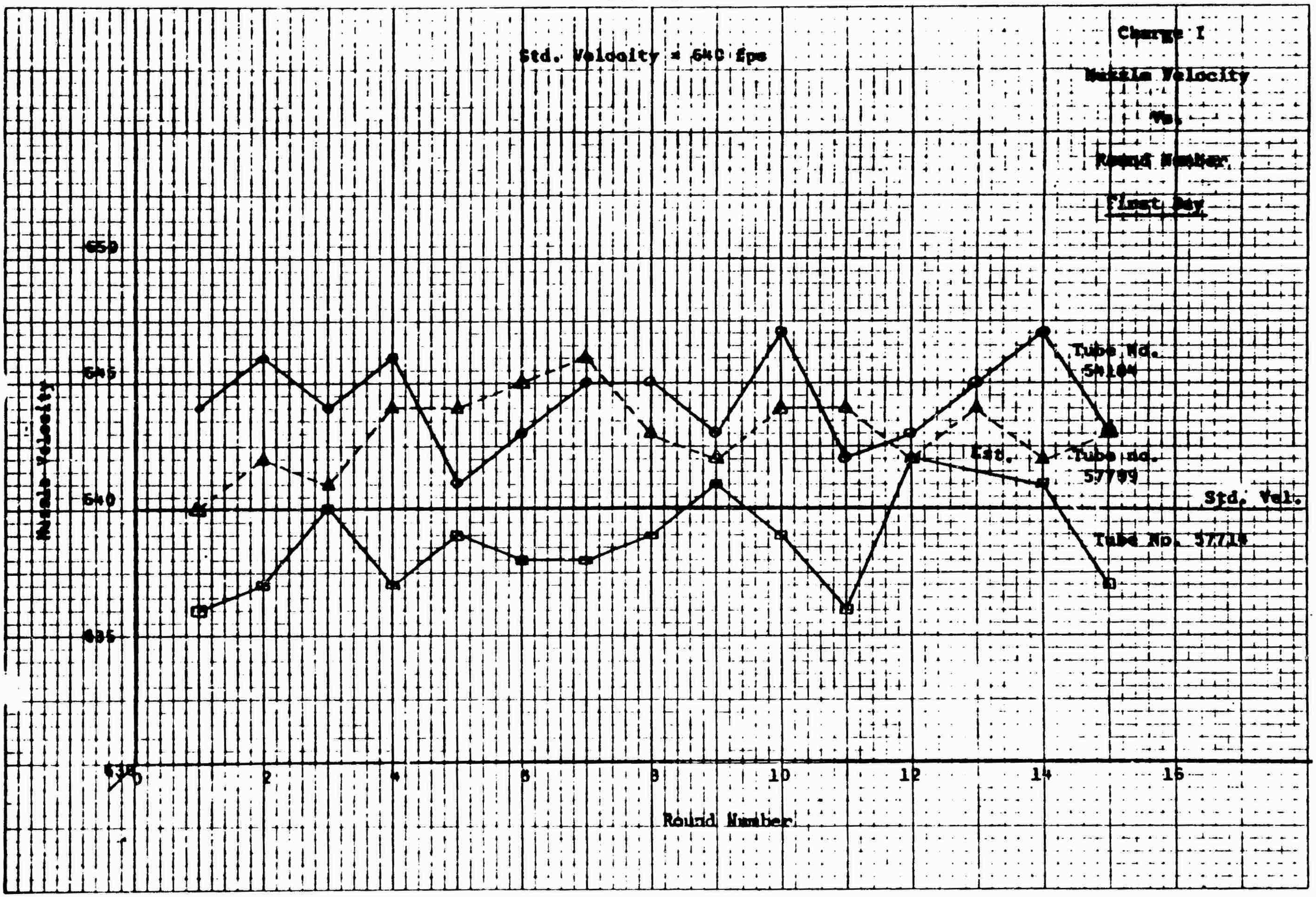
"The velocity creep problem is an age old problem associated with all howitzers when firing at the low zones without the benefit of conditioning rounds. To this extent the XM198 system proves no exception. A comparison test fired at APG on 5 April 1973 in which seven rounds of each the XM708, M549, XM708E1 and B4 (British round) were fired from the XM185 tube at Zone 1 of the XM164 charge at an elevation of 600 mils revealed the following results:

Prop.	Test Rd. Nos.	No. Rds. Cons.	MV fps	Std. Dev. fps	Range m	Std. Dev. m
XM708	67-73	6	658	5.3	3467	63.1
M549	74-80	7	672	7.3	3603	75.7
XM708E1	81-87	7	685	4.6	3761	41.7
B4	88-94	7	701	5.7	3903	74.5

"As can be seen the velocity was still increasing at the conclusion of this small test and it would be difficult to estimate when the velocity would level off. Such phenomena can result in precision and accuracy of fire problems when firing in the low zones, however, as stated before, this situation is not unique with the propelling charges for the XM198 howitzer."

"As to the memory and conditioning problem, the XM201 (Zones 6 and 7) and XM123 (Zone 8) propelling charges use triple base M30A1 propellant whereas the XM164 (Zones 1 through 5) propelling charge uses single base M1 propellant. The memory or conditioning effect due to the interactions caused when firing the two different types of propellant from the same tube could again lead to precision and accuracy problems because of the different velocity levels induced.

FIGURE I



Std. Velocity = 640 fps
Charge I
Muzzle Velocity
Vs.
Round Number
First Day
650
645
640
635
Muzzle Velocity
0
2
4
6
8
10
12
14
16
Round Number
Tube No. 54184
Tube No. 57789
Std. Vel.
Tube No. 57718

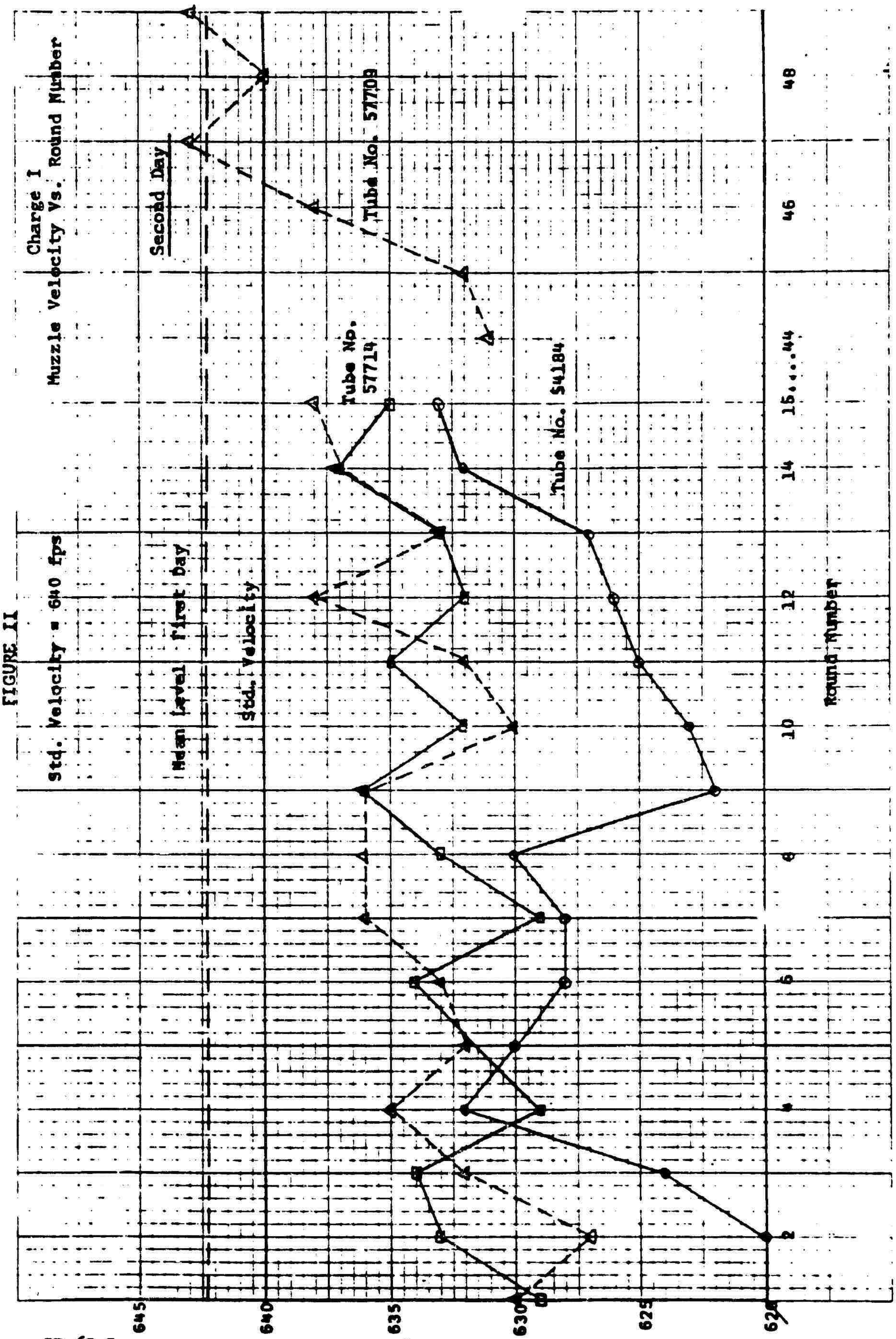


FIGURE II
Std. Velocity = 640 fps
Charge I
Muzzle Velocity Vs. Round Number
Second Day
Mean Level First Day
Std. Velocity
Tube No. 57714
Tube No. 54184
Tube No. 57709
645
640
635
630
625
620
Muzzle Velocity
2
4
6
8
10
12
14
15....44
46
48
Round Number

"Although the M72 propelling charge for the nuclear round for the 155mm Howitzer has a similar situation (Zone 3 is triple base and Zones 1 and 2 are single base) not enough rounds have ever been fired to get a good handle on the situation. However, it is known that minor changes in the chemical or physical composition of the propellant can cause quite sizeable changes in muzzle velocity due to the interactions involved. For example, when firing the 90mm gun, changes in velocity of the order of 40 f/s can occur when firing sulfated and non-sulfated rounds consecutively. Similarly, for the 155mm Howitzer it has been determined that larger dispersions can result from firing sulfated M4A1 charge lots with non-sulfated M4A1 charge lots in some mixed fashion. This increased dispersion occurs in all zones but is slightly larger in the lower zones.

"To illustrate this point the results of five surveillance stockpile reliability tests are summarized below. The first three tests were fired using a design in which the order of fire was purposely mixed, i.e., not more than two rounds from any one propellant lot were fired in succession. The last two tests were fired in a lattice design in which the order of fire was such that five or six rounds from any one lot were fired in succession. Most of these programs contained both sulfated and non-sulfated propellant lots. Knowing all of this it is of interest to note that the dispersion for the last two programs are smaller."

No. of Lots	No. of Sulfated Lots	Rd-to-Rd Std. Dev (fps)		
		Chg 3	Chg 5	Chg 7
20	18	5.4	5.6	4.9
16	8	7.8	7.8	5.8
16	12	6.9	5.0	4.9
20	17	4.6	5.4	4.9
14	14	4.3	5.1	5.4

Surveillance tests at proving grounds are normally controlled by firing tests in statistical designs with properly conditioned tubes at a set firing rate to minimize velocity trends. However, field tests or operational tests are not and should not be controlled to the extent of the proving ground tests. Therefore, it is important to be able to recognize velocity trends and their effect on accuracy so that a proper evaluation can be made from the results.

APPENDIX D

Complete Summary of Test Data

<u>Abbreviations</u>

MPI - Mean Point of Impact Registration

Check Rds - Check Rounds

LG TRANS - Long Transfer

ST TRANS - Short Transfer

HB REG - High Burst Registration

n - Sample Size or Rounds Considered

AVG - Average

SD - Standard Deviation

PE - Probable Error

QE - Quadrant Elevation

AZ - Azimuth

HOB - Hight of Burst

CORR MVV - Corrected Muzzle Velocity Variation from standard

SQ - Superquick

GI - Ground Impact

<u>Note</u>: MVV is corrected for powder temperature, projectile weight (M483A1) and M185 grooved tube bias.

Summary ZONE 3, M3A1 Charge

Date	Round/ Fuze	Fire Mission	Velocity Data n	Avg Vel	Corr MV	Vel SD	Target Miss n	Range Miss	Range SD	Range PE	Deflection Miss	Deflection SD	Deflection PE	QE	AZ	Set	Fuze Function n	Avg	SD	PE	HOB	HOB Miss
3 Oct 77	M107/M557	MPI REG		VELOCITY NOT AVAILABLE			6	-117	37.6	25.3	139	5.9	4.0	410	3104	SQ					G	
	M483/M577	CHECK RD					2	-19	—	—				404	3104	98					G	
	M483/M577	LG TRANS					4	80	13.3	9.0	19	3.7	2.5	619	3240	27.9		DATA LOST			126	26
	"	ST TRANS					4	123	14.8	10.0	16	2.9	1.9	421	3248	19.0					95	-5
	M107/M564	LG TRANS					2	81			13			505	3239	24.1					156	56
	"	ST TRANS					4	136	30.7	20.7	13	3.9	2.7	364	3248	17.0					92	-8
	"	HB REG					6	81	43.3	29.2	155	18.0	12.1	462	3104	20.9					205	5
	M483/M577	LG TRANS					4	45	12.9	8.7	7	22.0	14.9	585	3237	26.8					99	-1
	"	ST TRANS					4	20	31.3	21.1	23	3.8	2.5	400	3245	18.2					76	-24
	M107/M564	LG TRANS					3	28	10.8	7.3	14	3.5	2.4	481	3236	23.1					133	33
	"	ST TRANS					2	0	Dev 49m	—	28	—	—	350	3245	16.4					94	-6
	M483/M577	HB REG					6	101	17.2	11.6	151	14.6	9.8	515	3104	23.8					61	-39
	"	LG TRANS					4	-63	9.9	6.7	-9	6.3	4.2	576	3242	26.2					121	21
	"	ST TRANS					4	-25	17.8	12.0	-1	3.6	2.4	400	3251	18.0					91	-9
17 Oct 77	M107/M557	MPI REG	4	281.0	4.3	0.48	6	119	22.5	15.2	48	6.0	4.0	410	3104	SQ					G	
	M483/M577	CHECK RD	3	264.6	3.5	0.30	3	61	39.1	26.4	51	2.1	1.4	484	3104	GI					G	
	"	LG TRANS	4	264.5	3.2	0.77	4	-44	33.0	22.3	15	7.1	4.8	561	3220	26.0		DATA LOST			85	-15
	"	ST TRANS	4	263.8	2.5	0.46	4	-19	16.8	11.3	3	11.4	7.7	394	3231	18.0					75	-25
	M107/M564	LG TRANS	4	281.3	4.2	0.39	3	-31	11.7	7.9	15	10.4	7.0	468	3219	22.7					131	31
	"	ST TRANS	4	280.9	3.8	0.78	3	17	44.4	29.9	-1	6.6	4.4	344	3230	16.3					95	-5
	"	HB REG	9	270.8	-5.7	1.15	6	-81	42.8	28.9	65	24.8	16.7	462	3104	21.2					186	-14
	M483/M577	LG TRANS	4	258.7	-2.5	1.47	4	77	37.4	25.2	-3	3.6	2.4	639	3324	28.7					77	-23
	"	ST TRANS	1	259.1	-2.1	—	4	120	28.3	19.1	-13	3.3	2.2	421	3233	19.2					69	-31
	M107/M564	LG TRANS	4	279.1	2.5	1.02	2	93	—	—	-17	—	—	503	3222	24.1					172	72
	"	ST TRANS	2	279.2	2.5	—	4	103	40.2	27.1	-11	9.2	6.2	363	3233	19.1					156	56
	M483/M577	HB REG	4	263.5	2.3	0.80	6	71	10.9	7.3	50	6.2	4.2	514	3104	23.8					61	-39
	"	LG TRANS	2	263.3	2.2	—	3	-10	20.1	13.5	7	7.4	5.0	577	3220	26.3					57	-43
	"	ST TRANS	2	262.5	1.4	—	4	-37	19.7	13.3	-8	9.2	6.2	401	3231	18.1					120	20

Summary ZONE 3, M3A1 Charge (Continued)

			Velocity Data				Target Miss							Firing Data								
							Range				Deflection						Fuze Function					HOB
Date	Round/ Fuze	Fire Mission	n	Avg Vel	Corr MVV	Vel SD	n	Miss	SD	PE	Miss	SD	PE	QE	AZ	Set	n	Avg	SD	PE	HOB	Miss
26 Oct 77	M107/M557	MPI REG	6	276.5	0	0.75	6	-9	14.2	9.6	45	7.4	5.0	410	3104	SQ					G	
	M483/M577	CHECK RD	3	260.6	-.3	1.16	3	-59	36.1	24.4	56	1.5	1.0	483	3104	GI					G	
	"	LG TRANS	4	260.5	-.6	1.16	4	-30	14.7	9.9	22	10.6	7.2	592	3220	27.2	4	27.1	.10	.06	64	-36
	"	ST TRANS	4	261.5	0.4	1.44	4	11	20.6	13.9	2	6.3	4.2	406	3231	18.5	4	18.4	.06	.04	90	-10
	M107/M564	LG TRANS	4	277.4	0.6	1.61	3	-19	10.6	7.1	7	8.7	5.8	486	3219	23.6	3	23.6	.12	.08	118	18
	"	ST TRANS	4	279.6	2.8	0.87	3	30	37.8	25.5	0	2.5	1.7	353	3230	16.7	3	16.8	.15	.10	116	16
	"	H8 REG	10	280.9	4.0	1.11	5	54	52.3	35.3	72	16.6	11.2	436	3104	20.9	6	21.2	.58	.39	137	37
	M483/M577	LG TRANS	4	265.0	3.5	.68	4	91	10.8	7.3	-26	8.2	5.5	574	3226	27.0	2	26.8	—	—	58	-42
	"	ST TRANS	4	265.3	3.8	.50	4	66	5.7	3.9	-25	6.4	4.3	396	3236	18.4	4	18.4	.05	.03	86	-14
	M107/M564	LG TRANS	4	282.5	5.2	.60	3	18	55.7	37.6	-33	1.7	1.2	468	3225	23.0	3	23.0	.20	.13	130	30
	"	ST TRANS	4	282.4	5.0	.59	3	-20	18.3	12.4	-35	3.0	2.0	343	3236	16.4	3	16.3	.06	.04	124	24
	M483/M577	H8 REG	8	266.1	4.6	.96	6	125	22.1	14.9	64	3.2	2.1	514	3104	23.7	7	23.7	.09	.06	133	33
	"	LG TRANS	4	266.2	4.5	1.11		≈128						528	3221	24.9	4	24.8	.19	.13	72	-28
	"	ST TRANS	4	265.6	3.9	0.32	4	-109	21.0	14.2	-9	3.0	2.0	379	3232	17.4	4	174.	.08	.06	94	-6
22 Nov 77	M107/M557	MPI REG	5	280.2	2.3	0.88	6	85	17.9	12.1	165	7.9	5.3	410	3104	SQ					G	
	M483/M577	CHECK RD	3	262.3	0.5	1.05	3	36	54.0	36.4	160	0.6	0.4	484	3104	GI					G	
	"	LG TRANS	4	260.8	-0.9	1.55	4	-5	42.0	28.3	23	0.8	0.6	615	3244	27.5	3	27.4	.10	.07	157	-43
	"	ST TRANS	4	261.5	-0.2	.43	4	15	13.5	9.1	16	20.3	13.7	431	3255	18.6	4	18.5	.10	.07	182	-18
	M107/M582	LG TRANS	3	280.8	3.0	.83	4	109	47.9	32.3	26	9.8	6.6	505	3242	23.8	4	23.9	.06	.04	185	-15
	"	ST TRANS	4	280.8	3.1	.59	4	39	24.2	16.3	11	5.2	3.5	377	3253	16.8	4	16.8	.06	.04	202	+2
	"	HB REG	9	273.0	-3.8	1.47	6	-19	27.0	18.2	166	6.9	4.6	462	3104	21.4	6	21.4	.08	.08	101	-99
	M483/M577	LG TRANS	4	257.8	-3.3	1.05	3	44	27.5	18.6	-2	31.6	21.3	751	3250	31.6	4	31.6	.05	.03	269	69
	"	ST TRANS	4	258.0	-3.2	.66	4	65	18.8	12.7	-8	43.7	29.5	464	3255	19.5	4	19.6	.08	.06	207	7
	M107/M582	LG TRANS	3	277.4	0.5	.47	4	-12	21.4	14.4	21	13.3	9.0	549	3244	24.6	4	24.7	.08	.06	309	109
	"	ST TRANS	2	278.2	1.2	—	4	111	18.4	12.5	-1	3.9	2.6	401	3255	17.5	4	17.5	0	0	236	36
	M483/M577	H8 REG	8	259.3	-2.6	1.51	6	35	18.4	12.5	174	7.0	4.7	415	3104	23.8	3	23.7	.06	.04	29	-71
	"	LG TRANS	4	260.3	-1.6	1.93	4	-73	52.7	35.5	13	5.8	3.9	649	3246	27.9	4	27.8	.14	.10	290	90
	"	ST TRANS	4	260.5	-1.4	.95	4	5	16.8	11.3	20	11.0	7.4	446	3256	18.8	4	18.7	.05	.03	215	15

Summary
Zone 5, M3A1 Charge

Date	RD/Fuze	Fire Mission	Velocity Data: Powd Temp	Velocity Data: n	Velocity Data: Avg Vel	Velocity Data: Corr MVV	Velocity Data: Vel SD	Target Miss: Range: n	Target Miss: Range: Miss	Target Miss: Range: SD	Target Miss: Range: PE	Target Miss: Deflection: Miss	Target Miss: Deflection: SD	Target Miss: Deflection: PE	Firing Data: Elev	Firing Data: Az	Fuze Function: Set	Fuze Function: n	Fuze Function: Avg	Fuze Function: SD	Fuze Function: PE	Fuze Function: HOB	HOB Miss
	M107/M557	MPI Reg	56°					6	17	16.2	11.0	70	5.2	3.5	383	3216	SQ					G	
	M483/M577	Check Rds						3	-35			71											
	M483/M577	Lg Trans						4	-12	21.7	14.7	95	11.4	7.7	552	3193	33.4	3	33.5	0	0	17	-83
	M483/M577	Sht Trans						4	122	8.2	5.5	11	5.3	3.6	322	3236	19.5	2	19.5	-	-	58	-42
	M107/M564	Lg Trans						3	7	33.5	22.6	-13	7.1	4.8	496	3194	30.7	4	30.5	0.10	.06	119	18(Rd^{2}disc)
	M107/M564	Sht Trans						4	26	27.4	18.5	-5	4.1	2.8	300	3238	18.4	2	18.4	-	-	99	-1
5 Oct 77	M107/M564	HB Reg						6	60	58.5	39.5	61	1.6	1.1	399	3216	24.8	5	24.9	0.22	0.15	86	-14
	M483/M577	Lg Trans						4	-86	11.0	7.4	3	10.7	7.2	542	3192	32.2	4	32.3	0.05	0.03	122	22
	M483/M577	Sht Trans						4	4	20.9	14.1	11	4.9	3.3	316	3235	19.1	3	19.1	0	0	73	-27
	M107/M564	Lg Trans						2	-35	-	-	-14	-	-	491	3192	30.2	2	30.1	-	-	151	51
	M107/M564	Sht Trans						2	-41	-	-	3	-	-	299	3236	18.2	1	18.1	-	-	114	14
	M483/M577	HB Reg						7	68	21.8	14.7	62	3.3	2.2	432	3216	26.5	5	26.5	.09	0.06	44	-56
	M483/M577	Lg Trans						4	-16	9.3	6.3	-5	3.0	2.0	553	3193	32.7	4	32.7	0.10	0.07	135	35
	M483/M577	Sht Trans						4	24	18.5	12.5	-8	13.9	9.4	321	3236	19.2	4	19.2	0.06	0.04	80	-20
	M107/M577	MPI Reg	33°	6	378.3	5.2	1.06	6	-120	21.6	14.6	24	5.3	3.6	412	3304	SQ					G	
	M483/M577	Chk Rds	34°	3	355.0	-1.4	0.42	3	-161	8.5	5.7	30	5.1	3.5	449	3304	GI					G	
	M483/M577	Lg Trans	37°	4	355.2	-1.3	0.60	4	130	8.7	5.8	16	10.8	7.3	579	3310	34.3	4	34.2	0.10	0.07	96	-104(1 fz OL)
	M483/M577	Sht Trans	37°	4	355.3	-1.2	0.32	3	128	11.3	7.6	7	9.8	6.6	424	3305	25.2	4	25.2	0.06	.04	117	-83
	M107/M564	Lg Trans*	37°	4	378.3	5.0	0.57	1	148	-	-	-2	-	-	522	3311	31.5	3	31.5	0.40	0.27	182	-18
	M107/M564	Sht Trans	38°	4	378.3	5 .	0.71	4	41	37.0	24.9	-7	8.7	5.9	394	3307	23.6	4	23.5	0.13	.08	207	7
30 Nov 77	M107/M564	HB Reg	33°	7	375.4	2.3	0.89	6	-163	28.3	19.1	17	5.5	3.7	428	3304	26.6	6	26.5	0.12	.08	82	-18
	M483/M577	Lg Trans	33°	4	353.1	-2.9	0.39	4	141	5.6	3.8	-6	6.9	4.7	598	3312	34.9	4	34.8	0.05	.03	141	-59
	M483	Sht Trans	32°	4	353.5	-2.5	1.00	4	103	20.7	14.0	-4	4.7	3.1	431	3306	25.4	4	25.4	.06	.04	147	-53
	M107	Lg Trans	32°	4	377.4	3.4	.66	3	165	41.5	28.0	25	11.2	7.5	532	3312	31.8	4	31.9	.18	.12	196	-4
	M107	Sht Trans	32°	4	377.4	3.4	1.80	3	80	66.5	44.8	-27	6.0	4.1	400	3307	23.8	3	23.8	0.20	0.13	195	-5
	M483	R	33°	9	354.6	-1.4	0.49	6	6	33.0	22.3	36	16.0	10.8	485	3304	28.9	5	28.8	.08	.06	113	+13
	M483	Lg Trans	33°	4	355.1	-0.9	0.12	4	2	5.2	3.5	-12	5.1	3.4	589	3313	33.8	4	33.7	0	0	264	64
	M483	Sht Trans	33°	4	355.1	-0.9	0.60	4	28	18.3	12.3	-19	3.1	2.1	429	3308	24.9	4	24.8	.13	.08	200	0

*Two rounds discarded due to observer error.

LEGEND

MPI Reg - MPI Registration

Lg Trans - Long Transfer

Sht Trans - Short Transfer

Date	RO/Fuze	Fire Mission	Velocity Data				Target Miss							Firing Data								
								Range			Deflection					Fuze Function						HOB Miss
			n	Avg Vel	Corr MVV	Vel SD	n	Miss	SD	PE	Miss	SD	PE	QE	Az	Set	n	Avg	SD	PE	HOB	
	M107/M557	MPI Reg	5	376.1	2.3	.64	6	-63	19.3	13.0	94	4.4	3.0	412	3304	SQ					G	
	M483/M577	Chk Rd	3	355.3	-1.3	.55	3	-91	8.9	6.0	100	4.0	2.7	449	3304	Δ98					G	
	M483/M577	Lg Trans	4	355.0	-1.9	0.25	-	246			-17			583	3319	34.5		DATA LOST			99	-101
	M483/M577	Sht Trans	4	355.6	-1.4	.54	3	185	30.7	20.7	-25	9.2	6.2	426	3314	25.3					155	-45
	M107/M582	Lg Trans	4	378.6	4.3	.74	4	201	36.8	24.8	-1	9.3	6.2	516	3321	31.4					167	-33
	M107/M582	Sht Trans	4	378.6	4.2	.53	3	105	45.7	30.8	-24	13.7	9.3	390	3317	23.5					115	-85
21 Nov 77	M107/M582	HB Reg	5	378.6	4.2	.64	6	59	24.4	16.5	97	12.0	8.1	428	3304	26.8	6	26.9	.08	.05	59	-41
	M483	Lg Trans	4	355.5	-1.7	.59	4	1	28.5	19.2	12	6.0	4.0	571	3320	33.2	4	33.1	.05	.03	213	13
	M483	Sht Trans	4	356.4	-.8	.68	4	-42	15.2	10.2	9	13.4	9.0	417	3315	24.3	4	24.3	.05	.03	199	-1
	M107	Lg Trans	4	378.8	4.2	.89	4	-10	21.5	14.5	-4	7.4	5.0	512	3320	30.5	4	30.5	0	0	260	60
	M107	Sht Trans	4	378.0	3.4	1.53	4	-61	42.4	28.6	-6	7.8	5.2	388	3316	23.0	2	22.9	-	-	210	10
	M483	HB Reg	7	355.6	-1.6	.29	6	79	14.9	10.1	111	7.1	4.8	467	3304	28.7	5	28.6	.04	.03	16	-84
	M483	Lg Trans	4	356.5	-.7	.08	4	-56	19.8	13.4	-9	4.2	2.8	573	3323	33.1	3	33.0	.06	.04	252	52
	M483	Sht Trans	4	356.4	-.8	.46	4	-14	32.5	21.9	4	11.2	7.5	420	3318	24.4	4	24.3	.05	.03	204	4

Summary
ZONE 5, M4A2 Charge

			Velocity Data					Target Miss							Firing Data								
								Range				Deflection					Fuze Function						HOB
Date	Round/ Fuze	Fire Mission	Powd Temp	n	Avg Vel	Corr MVV	Vel SD	n	Miss	SD	PE	Miss	SD	PE	Elev	AZ	Set	n	Avg	SD	PE	HOB	Miss
31 Oct 77	M107/M557	MPI REG	47°	6	395.5	-0.4	1.41	5	49	20.2	13.6	-62	6.0	4.0	370	3305	SQ						
	M483	CHECK ROS	48°	3	381.1	-1.4	0.40	3	-3	21.4	14.4	-60	5.1	3.5	384	3305	GT						
	M483	TRANS	56°	3	379.9	-6.0	0.90	3	-52	3.5	2.4	33	4.0	2.7	518	3256	32.6	3	32.6	0.15	0.10	73	-77
	M107	TRANS		5	395.4	-1.3	0.72								DATA	LOST							
	M107	HB REG	48°	6	396.1	0.1	1.56	6	-17	17.4	11.8	-59	4.8	3.2	387	3305	24.9	6	24.8	0.05	0.04	116	+16
	M483	TRANS	49°	3	381.3	-1.7	0.83	1	68	—	—	34	—	—	545	3258	34.1	1	34.0	—	—	102	2
	M107	TRANS	48°	4	397.5	1.5	1.37	4	47	23.3	15.7	14	4.5	3.1	497	3259	31.9	4	32.0	0.05	0.04	63	-37
	M483	HB REG	48°	7	381.8	-0.7	1.22	6	86	19.3	13.0	-59	4.3	2.9	400	3305	25.8	6	25.8	0.04	0.03	46	-51
	M483	TRANS	46°	4	381.6	-0.8	0.71	4	-78	19.0	12.8	21	3.6	2.4	521	3258	32.6	4	32.7	0.39	0.26	115	15
8 Nov 77	M107/M557	MPI REG	44°	5	402.4	6.7	1.46	6	172	19.4	13.1	62	11.7	7.9	370	3305	SQ					G	
	M483/M577	CHECK ROS	44°	3	382.0	-0.3	1.45	3	34	36.9	24.9	28	32.0	21.6	384	3305	GI					G	
	M483	TRANS	44°	5	381.8	-0.5	0.80	3	-310	14.8	10.0	-45	9.7	6.6	505	3284	31.2	1	29.3	—	—	64	-136
	M107/M582	TRANS	44°	4	401.7	6.0	1.58	3	-191	97.9	66.0	-70	8.0	5.4	494	3285	30.5	4	30.4	0.36	0.24	111	+11
	M107/M582	HB REG	44°	7	400.0	4.1	2.33	6	0	24.7	16.7	75	8.2	5.5	387	3305	24.9	7	24.9	0.10	0.06	129	29
	M483	TRANS	44°	4	382.1	-0.2	1.17	4	35	42.8	28.9	-91	4.7	3.2	524	3288	33.3	3	33.3	0.12	0.08	31	-69
	M107	TRANS	44°	4	392.3	2.5	1.14	4	-3	37.9	25.6	-84	3.5	2.3	492	3289	31.7	4	31.7	0.06	0.04	62	-38
	M483	HB REG	44°	7	382.0	0.0	0.54	6	27	14.8	10.0	70	7.4	5.0	402	3305	25.9	6	25.8	0.05	0.04	64	-36
	M483	TRANS	45°	4	381.8	-1.3	0.77	4	-22	22.7	15.3	-142	11.8	8.0	532	3288	33.3	4	33.3	0.10	0.06	74	-26

Summary
Zone 7, M4A2 Charge

Date	Round/ Fuze	Fire Mission	Velocity Data n	Avg Vel	Corr Mvv	Vel SD	Target Miss n	Range Miss	Range SD	Range PE	Deflection Miss	Deflection SD	Deflection PE	Firing Data Elev	AZ	Fuze Function Set	n	Avg	SD	PE	HOB	HOB Miss
1 Nov 77	M107/M557	MPI REG	6	570.0	4.2	0.72	6	31	20.6	13.9	56	14.9	10.0	354	3160	SQ					G	
	M483/M577	CHECK RD	3	543.3	2.2	0.21	3	10	38.6	26.0	30	8.1	5.5	367	3160	98					G	
	M483/M577	TRANSFER	3	542.9	4.0	0.21	3	-83	31.0	20.9	-81	5.1	3.5	320	3234	26.5	4	26.5	0.06	0.04	n=3 149	-51
	M107/M564	"	4	569.2	3.9	0.68	4	-60	41.0	27.7	-12	27.6	18.6	313	3230	26.3	4	26.1	0.15	0.10	219	19
	"	HB REG	3	568.6	3.3	0.57	6	-17	38.3	25.8	141	60.7	41.0	354	3160	31.0	7	30.6	0.16	0.11	n=6 167	67
	M483/M577	TRANSFER	2	542.5	1.5	—	4	59	35.7	24.1	-62	7.6	5.1	321	3236	26.9	4	26.8	0	0	144	-56
	M107/M564	"	2	567.0	1.7	—	4	-1	50.8	34.3	-61	3.4	2.3	310	3239	26.5	4	26.8	0.10	0.07	196	-4
	M483/M577	HB REG	6	543.9	2.8	2.94	6	94	13.8	9.3	75	6.3	4.3	378	3160	31.6	5	31.5	0.09	0.06	73	-27
	M483/M577	TRANSFER	1	543.8	2.7	—	4	-21	31.9	21.5	-52	5.0	3.3	324	3234	26.6	Lost	—	—	—	181	-19
9 Nov 77	M107/M557	MPI REG	5	568.2	4.4	0.77	6	-314	77.2	52.0	-78	8.9	6.0	355	3160	SQ					G	
	M483/M577	CHECK RD	3	542.8	2.9	0.35	3	-341	13.1	8.8	-60	18.7	12.6	367	3160	98.0					G	
	M483/M577	TRANSFER	4	543.5	3.5	0.68	4	154	26.6	17.9	33	19.5	13.2	344	3218	28.3	4	28.3	0.10	0.06	130	-70
	M107/M564	"	4	568.3	4.4	0.39	3	17	49.4	33.3	33	23.6	15.9	331	3220	27.7	2	27.0	—	—	257	57
	"	HB REG	7	567.9	4.0	0.87	6	-400	40.9	27.6	-45	10.7	7.2	365	3160	31.0	6	30.4	0.42	0.28	134	34
	M483/M577	TRANSFER	4	543.1	2.9	0.39	4	128	16.2	10.9	21	4.3	2.9	344	3225	28.4	4	28.4	0.10	0.06	130	-70
	M107/M564	"	3	567.6	3.6	0.42	4	30	55.2	37.2	-16	32.6	22.0	332	3225	27.9	4	27.5	0.15	0.10	182	-18
	M483/M564	HB REG	8	543.2	3.0	0.83	5	-246	33.4	22.5	-55	26.1	17.6	377	3160	31.6	2	31.6	—	—	34	-66
	M483/M577	TRANSFER	4	543.6	3.4	0.73	4	25	43.9	29.6	2	18.3	12.3	342	3220	27.9	0	—	—	—	157	-43
23 Nov 77	M107/M557	MPI REG	7	570.7	3.2	3.03	6	166	26.3	17.7	-12	7.7	5.2	355	3160	SQ					G	
	M483/M577	CHECK RD	2	542.8	-0.1	—	2	288	—	—	-22	—	—	367	3160	GI					G	
	"	TRANSFER	4	544.9	1.9	0.54	4	109	22.1	14.9	47	6.8	4.6	316	3237	26.2	4	26.2	0	0	166	-34
	M107/M582	TRANSFER	0	—	—	—	4	98	32.4	21.9	-5	8.2	5.5	307	3231	25.7	4	25.7	0.12	0.08	205	5
	"	HB REG	6	572.3	4.1	1.41	6	199	26.2	17.7	-10	25.7	17.3	364	3160	30.8	4	30.9	0.05	0.03	124	24
	M493/M577	TRANSFER	2	543.7	0.9	—	4	69	54.8	36.9	14	51.2	34.5	315	3221	26.2	2	26.1	—	—	150	-50
	M107/M582	TRANSFER	3	570.6	3.2	0.67	3	104	23.8	16.0	11	11.9	8.0	304	3224	25.6	4	25.7	0.10	0.07	182	-18
	M483/M577	HB REG	4	543.5	0.7	0.53	6	201	26.9	18.1	-36	17.6	11.9	378	3160	31.6	6	31.6	0.10	0.07	187	-13
	M483/M577	TRANSFER	4	544.9	2.0	1.37	4	86	18.2	12.3	15	5.1	3.5	320	3223	26.2	0	—	—	—	209	9

Summary
ZONE 8, M119 Charge
28 Nov 1977

Round/ Fuze	Fire Mission	Velocity				Target Miss							Firing Data								HOB Miss
						Range				Deflection					Fuze Function						
		n	Avg	Corr MVV	SD	n	Avg	SD	PE	Avg	SD	PE	QE	AZ	Set	n	Avg	SD	PE	HOB	
M107/M557	MPI REG	5	670.6	3.4	3.28	6	-208	39.6	26.7	292	10.8	7.3	372	3169	SQ					G	—
M483/M577	CHECK RDS	3	644.0	3.3	1.91	3	146	24.5	16.6	215	49.3	33.3	396	3169	GI					G	—
"	LG TRANS	3	642.6	1.9	2.32	3*	368	33.3	22.5	44	4.6	3.1	517	3205	46.4	4	46.4	0.08	0.06	64	-136
"	ST TRANS	2	642.8	2.1	—	3*	425	22.0	14.8	-4	9.3	6.3	364	3241	34.4	4	34.4	0.05	0.03	120	-80
M107/M582	LG TRANS	4	670.0	2.8	1.35	4	59	20.7	14.0	8	27.4	18.5	484	3211	44.6	3	44.6	0.06	0.04	14	-186
"	ST TRANS	2	670.5	3.5	—	4	195	47.2	31.8	-35	6.7	4.5	341	3245	33.2	4	33.2	0.06	0.04	71	-129
"	HB REG	9	669.2	2.2	1.90	6	-75	16.0	10.8	244	8.0	5.4	388	3169	37.0	7	37.0	0.00	0.00	58	-142
M483/M577	LG TRANS	4	643.3	2.8	1.15	4	150	18.1	12.2	-7	9.1	6.2	529	3202	46.0	4	46.0	0.06	0.04	336	136
"	ST TRANS	2	645.8	5.3	—	4	258	43.0	29.0	-6	13.3	9.0	367	3237	33.8	4	33.8	0.08	0.06	266	66
M107/M582	LG TRANS	2	670.7	3.7	—	3*	-136	22.6	15.2	-36	15.0	10.1	490	3207	43.9	4	44.0	0.05	0.03	230	30
"	ST TRANS	3	669.6	2.6	0.67	4	-22	23.7	16.0	-34	5.4	3.7	345	3241	32.7	4	32.7	0.13	0.08	204	4
M483/M577	HB REG	6	644.6	3.9	0.86	3**	208	13.1	8.8	196	4.5	3.0	406	3169	38.5	3	38.4	0.06	0.04	28	-172
"	LG TRANS	4	643.2	2.5	1.22	4	-93	34.2	23.1	-18	11.6	7.8	497	3201	44.5	4	44.5	0.05	0.03	140	-60
"	ST TRANS	4	642.8	2.1	0.85	4	-40	58.1	39.2	-57	11.8	7.9	351	3238	33.0	4	33.0	0.06	0.04	161	-39

*One Round Lost
**10 rounds fired with 7 ground impacts. Three round registration.

APPENDIX E

Corrections to Fuze Setting of Fuze, MTSQ, M564
for Fuze, MTSQ, M582

DEPARTMENT OF THE ARMY Mrs. Willick/ajb/3880
U. S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
U. S. ARMY BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND 21005

DRDAR-BLL-FT 30 September 1977

SUBJECT: Corrections to Fuze Setting of Fuze, MTSQ, M564 for Fuze, MTSQ, M582

Commandant
US Army Field Artillery School
ATTN: ATSF-G-OP-A
CPT L. Hartsell
Fort Sill, OK 73503

1. Reference is made to DRDAR-BLL-FT letter dated 16 September 1977, subject, Test to Evaluate Use of 155mm, M107 Registration Data with 155mm, M483A1.

2. Inclosed are tables for charges 3 (M3A1), 5 (M3A1), 5 (M4A2), 7 (M4A2) and 8 (M119) to correct fuze setting of Fuze, MTSQ, M564 for Fuze, MTSQ, M582. To obtain fuze setting for the M582 Fuze, add to or subtract from the fuze setting of the M564 Fuze the given corrections.

Robert F. Lieske

Incls
as

ROBERT F. LIESKE
Actg Ch, Firing Tables Branch
Launch & Flight Division, BRL

CF

Pres, USAFAB, ATZR-BDOP (w/Incl)
AMSAA, DRXSY-RW (w/o Incl)
PM, SA, DRCPM-SA (w/o Incl)

CORRECTIONS TO FUZE SETTING OF FUZE, MTSQ, M564 FOR
FUZE, MTSQ, M582

FUZE SETTING FUZE M564 FROM	TO	CORRECTIONS
2.0	8.6	0.1
8.7	23.6	0.2
23.7	38.5	0.3
38.6	51.4	0.4

CORRECTIONS TO FUZE SETTING OF FUZE, MTSC, M564 FOR
FUZE, MTSC, M582

FUZE SETTING		
FUZE M564		CORRECTIONS
FROM	TO	
2.0	25.8	0.1
25.9	64.4	0.2

CORRECTIONS TO FUZE SETTING OF FUZE, MTSQ, M564 FOR
FUZE, MTSQ, M582

FUZE SETTING FUZE M564		CORRECTIONS
FROM	TO	
2.0	57.6	0.1
57.7	66.2	0.2

CORRECTIONS TO FUZE SETTING OF FUZE, MTSQ, M564 FOR
FUZE, MTSQ, M582

FUZE SETTING		
FUZE M564		CORRECTIONS
FROM	TO	
2.0	3.9	0.1
4.0	13.6	0.0
13.7	23.2	-0.1
23.3	32.9	-0.2
33.0	42.5	-0.3
42.6	52.1	-0.4
52.2	61.8	-0.5
61.9	71.4	-0.6
71.5	81.0	-0.7
81.1	83.1	-0.8

CHARGE
8

FUZE SETTING

PROJ, HE, M107
FUZE, MTSQ, M582

CORRECTIONS TO FUZE SETTING OF FUZE, MTSQ, M564 FOR
FUZE, MTSQ, M582

FUZE SETTING FUZE M564 FROM	TO	CORRECTIONS
2.0	6.8	0.0
6.9	11.7	-0.1
11.8	16.5	-0.2
16.6	21.4	-0.3
21.5	26.3	-0.4
26.4	31.1	-0.5
31.2	36.0	-0.6
36.1	40.8	-0.7
40.9	45.7	-0.8
45.8	50.6	-0.9
50.7	55.4	-1.0
55.5	60.3	-1.1
60.4	65.2	-1.2
65.3	70.0	-1.3
70.1	74.9	-1.4
75.0	79.8	-1.5
79.9	84.6	-1.6
84.7	89.5	-1.7
89.6	94.3	-1.8
94.4	95.3	-1.9

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